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Determinants of Offensive Scoring Efficiency in the Turkish Super League: A Linear Mixed-Model Approach

Türkiye Süper Ligi'nde Hücum Gol Verimliliğinin Belirleyicileri: Doğrusal Karma Model Yaklaşımı

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Abstract

Contemporary football performance analysis has moved beyond possession volume toward efficiency-based indicators that better reflect underlying performance capacity. This study examined contextual and temporal determinants of Offensive Scoring Efficiency (OSE; goals per minute of possession) in the Turkish Super League, with particular emphasis on match flow characteristics. Using a retrospective longitudinal cohort design, 680 team–match observations from 19 teams from the 2024–2025 season were analyzed. Ball-in-play time (effective playing time), team final league rank, and opponent final rank were included as fixed effects in a linear mixed-effects model with team-specific random intercepts (REML; Satterthwaite degrees of freedom). Mean OSE was 0.062 ± 0.055, while mean effective playing time was 48.89 ± 4.16 minutes. Team final rank was a significant negative predictor of OSE (B = –0.011, p = 0.003), indicating reduced scoring efficiency with lower team quality. Effective playing time was also inversely associated with OSE (B = –0.002, p = 0.007), suggesting that prolonged continuous play may constrain time-adjusted offensive productivity. Opponent final rank demonstrated a positive trend (B = 0.006, p = 0.055), reflecting higher efficiency against lower-ranked opposition. These results indicate that offensive scoring efficiency in elite football is shaped by both team quality and the temporal structure of match play. Importantly, greater effective playing time was associated with lower scoring efficiency, highlighting the potential role of match fragmentation and set-piece frequency in facilitating offensive output. The present findings support the use of efficiency-based metrics and mixed-effects modeling to better capture biologically and contextually grounded performance dynamics across competitive seasons.

Keywords Football; possession; offensive scoring efficiency; ball-in-play time; linear mixed model

Öz

Günümüzde futbol performans analizi, topa sahip olma süresinin miktarından ziyade, performans kapasitesini daha iyi yansıtan verimlilik temelli göstergelere doğru yönelmiştir. Bu çalışma, Türkiye Süper Ligi'nde Hücum Gol Verimliliğinin (OSE; topa sahip olunan dakika başına gol sayısı) bağlamsal ve zamansal belirleyicilerini, özellikle maç akışı özelliklerine odaklanarak incelemeyi amaçlamıştır. Retrospektif boylamsal kohort tasarımı kullanılarak, 2024–2025 sezonunda mücadele eden 19 takıma ait toplam 680 takım-maç gözlemi analiz edilmiştir. Oyunun akışta kaldığı süre (etkin oyun süresi), takımın sezon sonu lig sırası ve rakibin sezon sonu lig sırası, takım bazlı rastgele kesişimler içeren doğrusal karma etkili modelde sabit etkiler olarak modele dahil edilmiştir (REML; Satterthwaite serbestlik dereceleri). Ortalama hücum gol verimliliği 0.062 ± 0.055 olarak bulunurken, ortalama etkin oyun süresi 48.89 ± 4.16 dakika olarak hesaplanmıştır. Takımın sezon sonu lig sırası, hücum gol verimliliğinin anlamlı bir negatif yordayıcısı olarak belirlenmiştir (B = –0.011, p = 0.003); bu durum, takım kalitesi düştükçe gol verimliliğinin azaldığını göstermektedir. Etkin oyun süresi de hücum gol verimliliği ile ters yönde ilişkili bulunmuştur (B = –0.002, p = 0.007); bu bulgu, kesintisiz oyun süresinin uzamasının zaman uyarlanmış hücum üretkenliğini sınırlayabileceğini düşündürmektedir. Rakibin sezon sonu lig sırası ise pozitif yönde bir eğilim göstermiştir (B = 0.006, p = 0.055); bu durum, daha düşük sıralamadaki rakiplere karşı daha yüksek verimlilik elde edildiğini yansıtmaktadır. Bu sonuçlar, elit düzey futbolda hücum gol verimliliğinin hem takım kalitesi hem de maçın zamansal yapısı tarafından şekillendirildiğini göstermektedir. Özellikle daha uzun etkin oyun süresinin daha düşük gol verimliliği ile ilişkili bulunması, maçın parçalanması ve duran top sıklığının hücum çıktısını kolaylaştırıcı bir rol oynayabileceğine işaret etmektedir. Mevcut bulgular, verimlilik temelli ölçütlerin ve karma etkili modelleme yaklaşımlarının, rekabetçi sezonlar boyunca performans dinamiklerini biyolojik ve bağlamsal açıdan daha gerçekçi biçimde yakalamada önemli bir araç olduğunu desteklemektedir.

Anahtar Kelimeler Futbol; topa sahip olma; hücum gol verimliliği; oyunda kalma süresi (etkin oyun süresi); doğrusal karma model

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Introduction

The quantification of match performance in professional football has undergone a paradigm shift over the last decade. While early performance analysis focused primarily on the frequency of discrete events such as total shots, passes, or corners, contemporary research emphasizes the importance of process-oriented metrics that account for the sport's chaotic, low-scoring nature (Anderson & Sally, 2013; Mackenzie & Cushion, 2013). In this context, ball possession has traditionally been regarded as a proxy for dominance and offensive success. Indeed, early studies in major European leagues suggested a strong positive correlation between possession volume and match outcomes (Bloomfield et al., 2005; Lago-Peñas & Dellal, 2010). However, modern tactical evolutions have challenged this assumption, revealing a phenomenon often described as the "possession paradox." Recent evidence suggests that possession without penetration is often ineffective, and teams employing direct, counter-attacking styles can achieve superior results despite lower possession figures (Collet, 2013; Kempe et al., 2014). Consequently, the scientific focus has reoriented from the sheer volume of possession to Offensive Scoring Efficiency (OSE)—defined as the capacity to convert possession time into goals (Kubayi & Lago-Peñas, 2019).

Offensive efficiency, however, does not occur in a vacuum; it is heavily constrained by situational and contextual variables (Taylor et al., 2008). The "quality of opposition" and "team strength" are among the most robust determinants of tactical behavior (Gomez et al., 2013; Marcelino et al., 2011). Superior teams (higher-ranked) typically encounter opponents that employ low-block defensive strategies designed to minimize space, thereby forcing the stronger team to circulate the ball for extended periods without creating high-quality scoring chances (Yang et al., 2018). Furthermore, match status (winning, losing, or drawing) and venue (home advantage) have been shown to significantly alter tactical approaches, often forcing teams to prioritize risk-averse possession when leading (Bradley et al., 2014; Pollard, 2008). Conversely, when facing stronger opponents, lower-ranked teams often prioritize defensive organization and rapid transitions, potentially inflating their scoring efficiency per minute of attack by exploiting open spaces (Lago-Peñas et al., 2010).

A critical, yet frequently overlooked temporal variable in efficiency analysis is Ball in Play Time (or effective playing time). Research indicates that the actual duration of play in a 90-minute match can fluctuate significantly (typically between 50 to 65 minutes) due to stoppages, fouls, and strategic time-wasting (Link & de Lorenzo, 2016; Siegle & Lames, 2012). The "flow" or tempo of a match, dictated by how long the ball remains in play, fundamentally alters the physiological and tactical demands placed on players (Carling, 2013; Wallace & Norton, 2014). High effective playing time often correlates with continuous, rhythmic play, which may favor technically superior teams capable of sustaining possession. In contrast, fragmented games with low effective playing time are often characterized by frequent stoppages, which disrupt offensive rhythm and may level the playing field for technically inferior teams. Despite its potential importance, limited research has investigated how the effective duration of a match modulates a team's offensive scoring efficiency.

From a methodological standpoint, the statistical treatment of performance data in football research warrants scrutiny. A substantial body of literature relies on standard General Linear Models (e.g., ANOVA, simple regression) that treat match observations as independent data points. However, match performance data in a league format are inherently nested; observations are repeated measures derived from the same specific teams throughout a season. Ignoring this hierarchical structure (i.e., the non-independence of residuals) increases the risk of Type I errors and biased parameter estimates (Bates et al., 2015; Harrison et al., 2018; Winter, 2013). To mitigate these statistical limitations, Linear Mixed Models (LMM) offer a robust framework by incorporating random effects to control for team-specific variability while evaluating the fixed effects of contextual predictors.

Therefore, the primary aim of this study was to examine the determinants of OSE in the Turkish Super League using a linear mixed model framework. Based on theoretical underpinnings in performance analysis, it was hypothesized that team quality would be a primary driver of performance, with higher-ranked teams exhibiting greater efficiency than lower-ranked teams. Conversely, the quality of opposition was expected to constrain offensive output, such that efficiency would increase when facing lower-ranked opponents. Finally, regarding match tempo, it was postulated that higher effective playing time would support offensive rhythm and thus be positively associated with scoring efficiency.

Materials and Methods

Study Design and Participants

This study adopted a retrospective longitudinal cohort design to examine the determinants of offensive performance in professional football teams competing in the Turkish Super League during the 2024–2025 season. Match performance data were collected from all 19 teams in the league. Matches with incomplete or unreliable tracking data were excluded to ensure data quality. The final analytical sample comprised 680 team–match observations (n = 680), derived from official league matches, with each match contributing two team-level observations. Two observations were excluded from the final dataset due to missing values in selected covariates. The study protocol was approved by Bursa Uludağ University Faculty of Medicine Ethics Committee (Approval No: [2026/4-27]) and conducted in accordance with the Declaration of Helsinki.

Data Collection

Tactical and physical performance data were obtained from a validated professional sports analytics provider (Sportbase Analytics, Hungary). The league-wide optical tracking system captures player and ball positional data at a sampling frequency of 25 Hz. This system has demonstrated high validity and reliability for match-play performance metrics, with positional accuracy exceeding 98% in prior validation studies. All variables were standardized and temporally synchronized prior to data extraction and analysis.

Variables

Dependent Variable

The primary outcome variable was OSE, operationalized as the ratio of total goals scored to the cumulative duration of team ball possession (goals per minute of possession). Total possession time was defined as the total duration a team maintained controlled possession of the ball across all pitch zones (defensive, middle, and offensive thirds). This metric reflects the team's overall capability to convert possession time into goals, independent of the spatial context of possession build-up.

Independent Variables (Fixed Effects)

The following predictors were included as fixed effects: (1) Ball in Play Time: Total effective playing time (minutes) per match. (2) Team Rank: Final league position of the focal team at the end of the season. (3) Opponent Rank: Final league position of the opposing team.

Both ranking variables were treated as continuous covariates to examine linear associations between team quality and offensive scoring efficiency.

Statistical Analysis

All statistical analyses were conducted using JASP software (Version 0.95.4, Netherlands). Descriptive statistics are presented as mean ± standard deviation (SD). Normality of residuals was assessed using visual inspection of Q–Q plots and residual distributions. Given the hierarchical structure of the dataset—where repeated-match observations were nested within teams—the assumption of independence required by conventional linear regression was violated. To account for this clustering and to model team-specific dependencies, an LMM framework was employed. The random-effects structure included 'Team ID' as a random intercept to account for baseline performance differences across teams. The fixed-effects structure included Team Rank, Opponent Rank, and Ball-in-Play Time. Model parameters were estimated using Restricted Maximum Likelihood (REML). Statistical inference for fixed effects was based on the Satterthwaite approximation for degrees of freedom. Model fit was evaluated using Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). AIC and BIC values were used to compare model fit. Statistical significance was set at $p < 0.05$.

Results

Descriptive Statistics

The analysis included 680 valid match observations. The mean OSE was 0.062 ± 0.055, with values ranging from 0.000 to 0.320. The average effective playing time (Ball in Play) was 48.89 ± 4.16 minutes.

Table 1. Descriptive Statistics of Match-Play Temporal Parameters and Offensive Efficiency (n = 680).

Variable	Mean	SD	Minimum	Maximum
Minutes in Attack (min)	24.44	May.13	13.Tem	41.65
Ball in Play (min)	48.89	Nis.16	37.23	63.63
Offensive Efficiency	0.062	0.055	0.000	0.320

Note. SD = Standard deviation. Offensive Efficiency is calculated as the ratio of total goals scored to total ball possession time.

Linear Mixed Model Analysis

An LMM was used to identify predictors of OSE while controlling for the team-level random effect. The model fit statistics indicated a robust estimation (AIC = -1979; BIC = -1929). The results of the fixed effects analysis are summarized in Table 2.

Effect of Contextual Variables

Team Rank emerged as a significant negative predictor of OSE ($F_{(1, 19.70)}$ = 11.33, p = 0.003). The fixed effects estimate indicated an inverse relationship (B = -0.011, SE = 0.003), meaning that for every single position increase in league ranking (i.e., moving away from the 1st place towards the 19th), offensive efficiency significantly decreased. This confirms that top-ranked teams consistently achieved higher time-adjusted scoring productivity.

Opponent Rank showed a positive association with efficiency, which approached but did not strictly reach statistical significance ($F_{(1, 18.50)}$ = 4.19, p = 0.055). The coefficient (B = 0.006, SE = 0.003) suggests a trend in which teams tended to exhibit higher scoring efficiency against lower-ranked opponents (higher numerical rank), though this effect was less consistent than the team's own quality.

Effect of Temporal Parameters

Analysis of temporal parameters revealed that Ball in Play Time was a significant predictor of scoring efficiency ($F_{(1, 23.74)}$ = 8.63, p = 0.007). Interestingly, the relationship was negative (B = -0.002, SE = 0.001), indicating that matches with higher effective playing durations were associated with a slight but significant reduction in scoring efficiency per minute of attack.

Table 2. Fixed Effects Estimates for Predictors of OSE

Effect	*Estimate (B)*	*SE*	*t*	*p*
(Intercept)	0.153	0.029	5.23	<.001
Ball in Play Time	-0.002	0.001	-2.93	0.007*
Team Rank	-0.011	0.003	-3.37	0.003*
Opponent Rank	0.006	0.003	2.05	0.055

Note. SE = Standard Error. The estimate represents unstandardized coefficients.
Significance set at p < 0.05.

Discussion

The primary aim of this study was to identify the determinants of Offensive Scoring Efficiency (OSE) in the Turkish Super League using a Linear Mixed Model (LMM) framework. By accounting for the hierarchical structure of match data—a methodological refinement often overlooked in previous literature (Bates et al., 2015; Harrison et al., 2018)—this study revealed that both team quality and the temporal dynamics of the match significantly predict offensive productivity. Consistent with our first hypothesis, Team Rank emerged as a robust negative predictor of OSE, indicating that higher-ranked teams are significantly more efficient at converting possession into goals. This finding aligns with established literature suggesting that superior teams possess higher technical capacity and tactical maturity (Di Salvo et al., 2009; Rampinini

et al., 2009), allowing them to exploit scoring opportunities even when facing defensive "low blocks" (Gomez et al., 2013; Yang et al., 2018). Similar trends have been observed in the English Premier League and Spanish La Liga, where top-tier teams consistently outperform mid-table teams in technical efficiency metrics despite varying physical demands (Bush et al., 2015; Dellal et al., 2011). Our results confirm that this hierarchy of efficiency is also prevalent in the Turkish Super League, supporting the notion that "possession quality" outweighs "possession volume" (Collet, 2013; Kubayi & Lago-Peñas, 2019).

In contrast to the expected results regarding team quality, the most novel finding of this study concerns the negative relationship between Ball in Play Time and OSE. We initially hypothesized that higher effective playing time would foster offensive rhythm. However, the results indicate that matches with longer continuous play durations are associated with lower scoring efficiency. Two plausible mechanisms may explain this. First, high effective playing time implies fewer stoppages. Stoppages are precursors to set-pieces, which are high-probability scoring events (Anderson & Sally, 2013; Casal et al., 2015). In matches with extended play, teams rely on open-play build-ups against organized defenses, which are inherently harder to break down. Second, frequent interruptions fragment the game, potentially preventing inferior teams from maintaining defensive concentration (Link & de Lorenzo, 2016; Wallace & Norton, 2014). This contradicts findings from some high-tempo leagues, where fluid play is linked to success (Carling, 2013), suggesting that the Turkish Super League may possess unique tactical characteristics in which "chaos" and fragmentation favor offensive output. Regarding the contextual constraints of the opposition, our analysis revealed a positive trend ($p = 0.055$), suggesting that efficiency tends to increase when facing lower-ranked opponents. Although this effect marginally exceeded the significance threshold, the coefficient's direction is consistent with the "quality of opposition" theory (Lago-Peñas & Dellal, 2010; Lago-Peñas et al., 2010). The lack of strict statistical significance might be attributed to the league's competitive balance or to mid-table teams' tendency to adopt highly conservative approaches against stronger peers, thereby narrowing the efficiency gap.

From a methodological perspective, this study underscores the importance of using Linear Mixed Models in performance analysis. Previous research utilizing standard regression often ignores the nested nature of season-long data (Sarmento et al., 2014). By incorporating 'Team ID' as a random effect, our model successfully partitioned the variance attributable to inherent team characteristics from the variance explained by match-specific predictors. This approach provides more accurate parameter estimates and reduces the risk of Type I errors, offering a more rigorous template for future longitudinal studies in sports science (Bates et al., 2015).

This study is not without limitations. The analysis was restricted to a single season (2024–2025) in the Turkish Super League; thus, the generalizability of the findings to other European leagues remains to be tested. Furthermore, although we controlled for possession volume by normalizing the dependent variable, we did not explicitly differentiate between 'open-play' and 'set-piece' efficiency. Future research should integrate physical metrics and advanced tactical data into mixed models to further unravel the complexities of offensive performance (Kempe et al., 2014).

Conclusion

This study demonstrates that offensive scoring efficiency is not merely a product of possession volume but is significantly determined by team quality and the temporal flow of the match. Crucially, the negative association between effective playing time and

efficiency challenges the assumption that fluid games are always more productive. For coaches and analysts, these findings suggest that while dominant possession is desirable, the ability to capitalize on match fragmentation and maintain efficiency during low-tempo intervals is equally critical for success.

Kısaltmalar / Abbreviations

ANOVA — Analysis of Variance

BMI — Body Mass Index

SD — Standard Deviation

$\bar{X}$ — Mean

SPSS — Statistical Package for the Social Sciences

t — t test value

F — F test statistic

p — Significance value

n — Sample size

N — Total number of participants

Min — Minimum value

Max — Maximum value

kg — Kilogram

SS — Standard deviation (or variability measure in tables)

d — Cohen's d effect size

Beyanlar / Declarations

Etik Onay ve Katılım Onayı / Ethics approval and consent to participate

Bu çalışmanın hazırlanma ve yazım sürecinde "Yükseköğretim Kurumları Bilimsel Araştırma ve Yayın Etiği Yönergesi" kapsamında bilimsel, etik ve alıntı kurallarına uyulmuş olup; toplanan veriler üzerinde herhangi bir tahrifat yapılmamış ve bu çalışma herhangi başka bir akademik yayın ortamına değerlendirme için gönderilmemiştir. Makale ile ilgili doğabilecek her türlü ihlallerde sorumluluk yazarlara aittir.

During the preparation and writing of this study, scientific, ethical and citation rules were followed in accordance with the "Higher Education Institutions Scientific Research and Publication Ethics Guidelines"; no alterations were made to the collected data, and this study has not been submitted to any other academic publication platform for evaluation.

Veri Ve Materyal Erişilebilirliği / Availability of data and material

Bu çalışmanın bulgularını destekleyen veriler, makul talepler üzerine sorumlu yazardan temin edilebilir. Veri seti yalnızca akademik amaçlar için erişilebilir olacak ve verilerin herhangi bir kullanımı, orijinal çalışmayı referans gösterecek ve katılımcıların gizliliğini koruyacaktır.

The data that support the findings of this study are available from the corresponding author upon reasonable request. The dataset will be accessible only for academic purposes, and any use of the data will recognize the original study and maintain the confdentiality of the participants.

Çıkar Çatışması / Competing interests

Yazar, bu makalede sunulan çalışmayı etkileyebilecek herhangi bir çıkar çatışması veya kişisel ilişkiye sahip olmadığını beyan etmektedir.

The author declares that there are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Yazar Katkıları / Authors' Contribution Statement

Yazar, makalenin tüm aşamalarını yürütmüş, içeriğini eleştirel olarak gözden geçirmiş ve makalenin son halini onaylamıştır.

The author conducted all stages of the study, critically reviewed the content, and approved the final version of the manuscript.

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