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Quantifying and modelling the game speed outputs of English Championship soccer players

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ABSTRACT

This study aims to quantify and model the game-speed demands of professional soccer players competing in the English Championship league, to compare the effect of match location and to examine the effect of playing position on game-speed outputs across the season. Twenty-eight male professional soccer players were enrolled. Moving average calculations were applied to the raw GNSS (STATSports) speed data of each player's duration matches (home = 14 and away = 9). Positional groups were centre-back (CB), full-back (FB), centre-midfield (CM), wing-midfield (WM) and centre-forward (CF). The maximum value across each of the moving average window durations was extracted and converted to units of metres per minute. Power-law models were fitted to all observations (R2 = 0.64), home only (R2 = 0.98), and away only (R2 = 0.98). No significant effects are observed in game-speed outputs when home and away games are analysed. Significant differences were seen between the following positional groups; CBvs.CF ($d = -0.323$), CM ($d = -0.530$) and FB ($d = -0.350$). CM displayed positive difference compared to WM ($d = 0.614$). This study reported power-law model fitted game speed. Players' positional groups have significantly different game-speed demands, which should be considered during match analysis and training periodization. This study found that game speed is not affected by the location of the match.

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Football; team sports; GPS; speed

Introduction

Soccer is a physically demanding sport where both aerobic and anaerobic systems are taxed during intense activities, such as sprints, accelerations, decelerations and change of directions, alongside sport-specific technical actions, such as tackles, headings, passes, and shots (Beato & Drust, 2020; Beato & Jamil, 2018; Mohr et al., 2005). Soccer players generally cover a total distance of 10–13 km during a game, which is typically associated with the player's position, where external roles (*e.g.*, wings), for tactical motivations, cover longer distances compared to internal positions (*e.g.*, central backs) (Borghi et al., 2020; Christopher et al., 2016; Mohr et al., 2003; Tierney et al., 2016). Thus, physical conditioning

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is of high importance to coaches, practitioners and researchers alike in soccer (Mohr et al., 2003, 2005).

In the last years, external training load monitoring has become one of the most important necessities for sport science departments (Akubat et al., 2014). External load data are used to support sport science staff and coaches to make informed decisions during the training microcycle and mesocycle (Gualtieri et al., 2020). For instance, coaches routinely use external training load to ensure adequate recovery is provided to players between training sessions and matches throughout the soccer season (Vanrenterghem et al., 2017). The correct monitoring and following planification of the training load can have a key impact on the long-term efficiency of the squad and for the maximization of physical and physiological adaptations (Beato, Coratella et al., 2018; Chmura et al., 2019; Vanrenterghem et al., 2017). This is particularly true when considering professional soccer team schedules which can be very demanding and can reduce the training availability between official matches (Gualtieri et al., 2020). The metrics that are generally analysed are total distance, relative velocity, high-speed running, peak velocity, accelerations and decelerations (Andrzejewski et al., 2018; Beato et al., 2020; Gualtieri et al., 2020; Stevens et al., 2017). The instrumentations usually utilized to monitor external load parameters are global navigation satellite systems (GNSS) and video-tracking systems (Beato & Jamil, 2018; Cummins et al., 2013). Both these systems give the user the possibility to evaluate external load variables; however, GNSS is currently the most common instrument used in elite soccer departments because it can be used during both matches and training sessions (Beato, Devereux et al., 2018; Vanrenterghem et al., 2017). In this study, the STATSports Apex GNSS device was used to capture match day speed and displacement data. The Apex GNSS is capable of acquiring and tracking multiple satellite systems (*e.g.* global positioning systems, GLONASS, BeiDou) to provide the best possible positional information (Beato, Coratella et al., 2018) in varying environments. The validity and reliability of this specific GNSS model has been previously reported (Beato, Coratella et al., 2018; Beato & De Keijzer, 2019).

Recent evidence confirms that soccer matches are a critical training component of the week (Anderson et al., 2016; Morgans et al., 2018). During a match, players perform, relative distances (RD), high-speed running, and soccer-specific activities that can be difficult to recreate during training sessions or during congested fixture micro-cycles (Gualtieri et al., 2020; Jones et al., 2019). However, the majority of research analysing match demands has focused its attention on average values without considering the most intense periods (*e.g.* worst-case scenario) (Delaney et al., 2018). For this reason, training sessions and drills that replicate the average match demands could underestimate the intensity of the most demanding moments of the game. To overcome this issue, running intensity has been evaluated using time blocks between 5 and 15 min (Bradley & Noakes, 2013). Additionally, game speed (represented as RD) calculated using a moving average technique has been recently used to elucidate this issue of underestimating the most intense periods of a match in team sports (Delaney et al., 2017). Previous research has reported that RD can be over 170 m·min^{-1} when analysed using short time windows (*e.g.* 1 min) (Delaney et al., 2018). This game-speed intensity is much higher than the average RD (*e.g.* around 120 m·min^{-1}) reported considering whole games (Mohr et al., 2005; Stevens et al., 2017). Furthermore, mathematical models assessing the relationship between running intensity and duration (moving average) have shown to be a valid way to quantify soccer match intensity and account for true periods of maximal player output (Delaney et al., 2018). Sports Scientists and coaches can use this information for training load management during training microcycles in order to construct training drills of an appropriate intensity and expose players to match-like running conditions (Konefał et al., 2019).

Effective soccer training prescription is especially important because professional players generally have very limited time available for specific physical training because of travel commitments, recovery, and the need for tactical and technical skills training (Beato et al., 2019). To date, information related to match day in-season external load and mathematical models used to evaluate game speed in professional soccer players is limited and such information may help sports scientists and coaches to adequately prepare their soccer players. Therefore, the aim of this study was to firstly quantify and model the game-speed demands of professional soccer players competing in the English Championship league, secondly to compare the effect of match location on game-speed outputs, and lastly to examine the effect of playing position on game-speed outputs across the season. The authors' hypothesis was that game speed is affected by the time window being analysed, by the location of the match (home vs. away), and by the players' positional group.

Methods

Participants

Twenty-eight male professional soccer players of the same team were enrolled in this study (age; 25.3 ± 4.2 years, body mass; 79.5 ± 6.3 kg, height; 1.82 ± 0.07 m). All participants and the club were informed about the risk and benefits of the study and a consent form was signed. Inclusion criteria were the absence of any injury or illness (based on team medical staff) and regular participation in soccer training and competition. Only outfield players' data were analysed in this study, while goalkeepers were excluded. The players were professional players of the English championship with several years of professional experience (>5 years). The data analysis was performed during the official season 2019/20 and did not include any friendly matches. Player names were anonymized before the data analysis, which was performed blindly by a researcher non-affiliated with the club. The Ethics Committee of the University of Suffolk (Ipswich, UK) approved this study (RETH19/050) . All procedures were conducted according to the Declaration of Helsinki for human studies.

Experimental design

This descriptive study evaluates the game-speed outputs of professional Championship players using moving average windows of varying sizes and mathematical modelling techniques (Delaney et al., 2018). This study also compared the effects of match location on game-speed outputs. In addition, the game-speed demands of different player positions during the official season have been compared to determine if statistical differences exist. External training load data were recorded as part of the normal monitoring routine of the team. Twenty-three matches were analysed in this study, of which 14 were home games, and 9 were away games. Positional groups were defined as centre back (CB), full back (FB), centre midfield (CM), wing midfield (WM) and centre forward (CF).

External training load

External training load parameters were recorded during matches using 10 Hz GNSS units (STATSports, Apex, Northern Ireland). The GNSS units were turned on approximately 10–15 min before the beginning of the match. Meanwhile, the subjects performed a warm-up routine with the fitness coach of the team. During the matches, one GNSS unit was placed on the back of each player by means of a harness at the level of the chest. The Apex GNSS model reports information about the quality of the signals such as the number of satellites and dilution of precision. In this study, the number of satellites was 16.1 ± 1.9 and dilution of precision was 2.38 ± 0.60. Players consistently wore the same GNSS unit during each match to avoid inter-unit variability (Beato, Devereux et al., 2018). Total distance in metres and relative velocity calculated as the ratio between total distance and the total time were measured and analysed (Gaudino et al., 2013). GNSS data recorded by the units were downloaded and further analysed with STATSports Software (Apex version 3.0.02011). The validity and reliability of the Apex GNSS unit was previously calculated during sport-specific activities. The bias reported for distance was between 1.05% and 2.3%, respectively (Beato, Coratella et al., 2018). The inter-unit reliability for speed was classified as *excellent* and the coefficient of variation was *good* (<5%) (Beato & De Keijzer, 2019).

Game-speed modelling

In order to model game-speed data, the protocol previously presented by Delaney et al., 2018 was utilized. Briefly, this involved exporting raw GNSS data at a sampling rate of 10 Hz for each player across all matches. A custom computer program written in the Python programming language (Version 3.6.5, Anaconda Inc, New York, USA) was then used to clean the raw data, removing dead time (half time, extra time) and excluding any match files where a player had less than 60 minutes of data. Moving average calculations were then applied to the GNSS Doppler speed data of each player using 10 different moving average window durations (1, 2, 3, … 10). The maximum value across each of the moving average window durations was then extracted and converted to units of metres per minute ($m \cdot min^{-1}$) for further statistical analysis (Delaney et al., 2018; Zinoubi et al., 2017).

Statistical analyses

All statistical analyses were performed using JASP software (version 0.9.2; JASP, Amsterdam, The Netherlands). Descriptive statistics are reported as mean ± standard deviation (SD) or mean ± 95% confidence intervals (CI) unless otherwise stated. Model fitting was conducted using nonlinear least-squares regression, and goodness-of-fit statistics are reported using the coefficient of determination (R2). Measures of goodness-of-fit summarize the discrepancy between observed values and the values expected under the model in question. A multivariate analysis of variance (MANOVA) was used to test for significant effects in game-speed outputs when games are played at home compared to away (Harrell, 2015). The total observations analysed for home and away matches was n = 96 and n = 36. A repeated measures analysis of variance (RMANOVA) was used to test for between-player positional group differences in game-speed outputs. Where Mauchly's test of sphericity has been found to be significant, Greenhouse–Geisser corrections have been applied. Post-hoc analysis was performed using Bonferroni corrections (applied to the alpha value). Significance was set at $p < 0.05$ and reported to indicate the strength of the evidence alongside the effect size. Results are reported using p-values and Omega squared (ω^2) effect sizes. Based on the Cohen's *d* values revised by Hopkins effect sizes are interpreted as follows: *trivial* < 0.2; 0.2 ≤ *small* < 0.6; 0.6 ≤ *moderate* < 1.2; 1.2 ≤ *large* < 2.0; *very large* > 2.0 (Hopkins et al., 2009).

Results

All models demonstrated *acceptable* to *near perfect* fits (Harrell, 2015), Figure 1 displays the power-law model fitted to all observations (R2 = 0.64). Figure 2 displays separate models fitted to the home only (R2 = 0.98) and away only (R2 = 0.98) observations.

The results of the MANOVA test detailed in Table 1 demonstrate that no significant effects are observed in the dependent variables (game-speed outputs) when the independent variables (home & away games) are manipulated.

The results of the RMANOVA for between-subject effects are detailed in Table 2. Significant *moderate* mean game-speed output differences were found between player positional groups ($p < 0.001$, $d = 0.093$).

The results of a post hoc analysis for the between-subject effects are detailed in Table 3. Significant differences are seen between the following positional groups; CB displayed

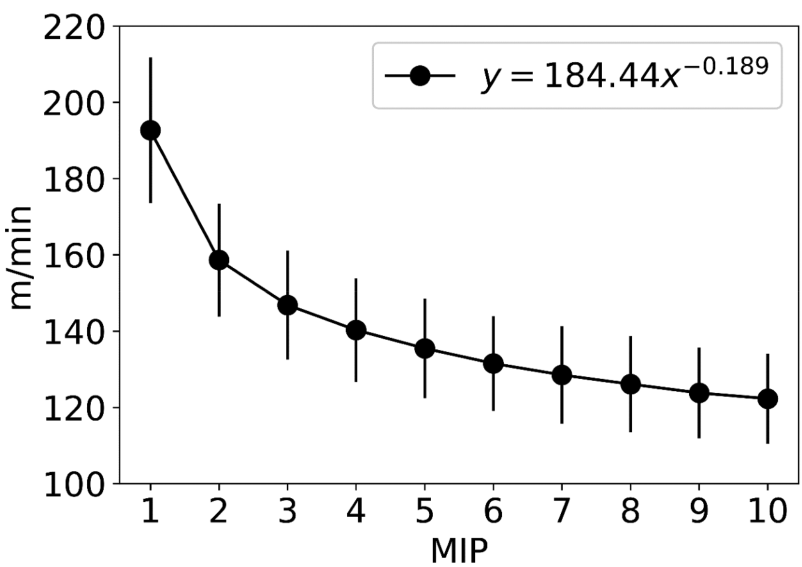

Figure 1. Game-speed Power-Law model fitted to all observations. Data reported as mean ± standard deviation.

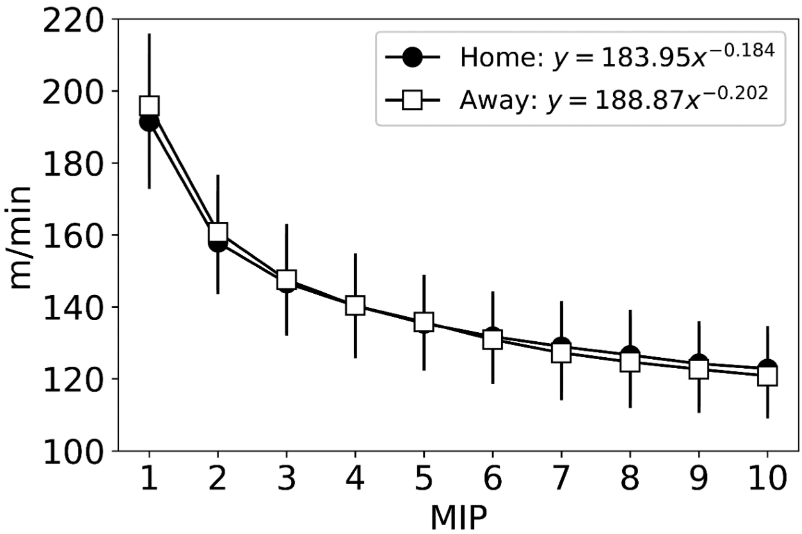

Figure 2. Game speed Power-Law models fitted to the Home only & Away only game observations. Data reported as mean ± standard deviation.

Table 1. MANOVA: Pillai Test.

Cases	df	Approx. F	Trace $_{Pillai}$	Num df	Den df	p
(Intercept)	1	1675.016	0.993	10	121.000	< .001
Game	1	1.378	0.102	10	121.000	0.199
Residuals	130					

Table 2. RMANOVA Between Subjects Effects.

Cases	Sum of Squares	df	Mean Square	F	p	ω2
Player Position	66,252.609	4	16,563.152	15.380	< .001	0.093
Residuals	119,540.043	111	1076.937			

Table 3. Post Hoc Comparisons – Player Position.

			95% CI for Mean Difference						
		Mean Difference	Lower	Upper	SE	t	Cohen's d	p	
CB	CF	−12.120	−22.090	−2.150	3.481	−3.482	−0.323	0.007	**
	CM	−18.497	−27.784	−9.210	3.242	−5.705	−0.530	< .001	***
	FB	−11.357	−19.996	−2.717	3.016	−3.765	−0.350	0.003	**
	WM	1.041	−7.539	9.622	2.996	0.348	0.032	1.000	
CF	CM	−6.377	−16.241	3.487	3.444	−1.852	−0.172	0.667	
	FB	0.763	−8.493	10.020	3.232	0.236	0.022	1.000	
	WM	13.162	3.960	22.363	3.213	4.097	0.380	< .001	***
CM	FB	7.140	−1.376	15.657	2.974	2.401	0.223	0.180	
	WM	19.539	11.082	27.996	2.953	6.617	0.614	< .001	***
FB	WM	12.398	4.658	20.139	2.702	4.588	0.426	< .001	***

Notes: *p < .05, **p < .01, ***p < .001

small negative differences in output compared to CF (p = 0.007, *d* = −0.323), CM (p < 0.001, *d* = −0.530) and FB (p = 0.003, *d* = −0.350). CF displayed a *small* positive difference compared to WM (p < 0.001, *d* = −0.380). CM displayed a *moderate* positive

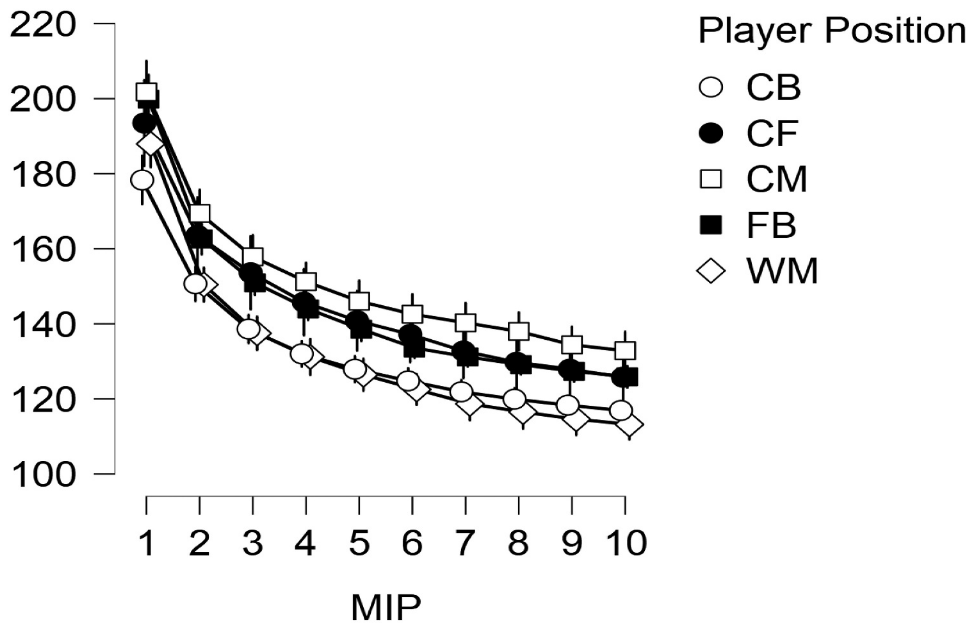

Figure 3. Mean ± 95% CI game-speed output per player positional group over 1–10 minute moving average periods.

difference compared to WM ($p < 0.001$, $d = 0.614$). FB displayed a *small* positive difference compared to WM ($p < 0.001$, $d = 0.426$). Figure 3 shows game-speed output per moving average window by player positional group.

Discussion

The aim of this study was: firstly to quantify and model the game-speed demands of professional soccer players competing in the English Championship league; secondly to compare the effect of match location on game-speed outputs; and lastly to examine the effect of playing position on game-speed outputs across the season. In agreement with the author's hypothesis, game speed is affected by the time window being analysed, where higher speed has been found analysing short time intervals (*e.g.* 1–2 minutes vs. 10 minutes) and by the players' positional group (*e.g.* CM vs. WM). Contrariwise, this study found that game speed is not affected by match location (home vs. away). The findings of this study provide new information related to match day game-speed outputs of professional soccer players competing in the English Championship running. The mathematical models fitted to the game-speed outputs in this study can assist in profiling the competitive running demands of Championship soccer. It also provides an objective anchor to design training drills that replicate match day running demands.

The game-speed model was fit using 10 different moving average window durations (Delaney et al., 2018) and reported in Figure 1, which displays the power-law model fitted to all observations (R2 = 0.64). Game speed is as expected higher during short window durations (*e.g.* 1 min > 180 $m{\cdot}min^{-1}$) compared to longer window durations (*e.g.* 10 min approximately 130 $m{\cdot}min^{-1}$). The data reported in the current study are similar to those previously reported by Delaney et al., 2018. Our study reports that English Championship players have RDs > 180 m·min^{-1} and 160 m·min^{-1} during short window durations (1 min and 2 min duration, respectively) compared to previous research analysing elite players of the Australian A-League, who reported lower RD of around 175 m·min^{-1} and 155 m·min^{-1} using the same windows durations (1 and 2 min) (Delaney et al., 2018). Conversely, game-speed differences cannot be observed when longer window durations (*e.g.*, 9–10 min) are compared between the two studies. Delaney et al., 2018 reported RD between 120 and 130 m·min^{-1}, which are similar to the RD reported in the current study, *e.g.* 130 m·min^{-1}. Therefore, the current study analysing professional English Championship players presented higher RD during games compared with Australian A-League players only when short window durations were analysed. This comparison further highlights the utility of the modelling approach used in this study, which provides a more granular description of the match day running demands of competitive soccer compared to traditional methodologies (Mohr et al., 2005). Sports scientists and soccer coaches can use these innovative findings to physically prepare their players for the demands of the matches and determine if adjustments are required when a team is going to compete in a different league or competition. The differences between the game-speed outputs in the two studies may be explained by the physical fitness levels of the two cohorts of players studied, the higher game demands of the English Championship compared to Australian A-League, or simply because of different tactical strategies used by the two teams in their respective leagues (Rampinini et al., 2007; Sæterbakken et al., 2019; Wells et al., 2012; Winter & Pfeiffer, 2016). Future research may compare the RD and other training load variables between the two leagues to verify these hypotheses.

This study reported power-law models fitted to the home (R2 = 0.98) and away (R2 = 0.98) observations (Figure 2). Therefore, both models reported in this research can be used to prescribe game-speed specific intensity during drills of various durations with a high degree of accuracy. However, we did not find any significant difference between home and away games following MANOVA analysis (Table 1). This is an interesting finding which suggests that it is not necessary to independently assess game-speed demands on the basis of the match location; both home and away game-speed values can be interpolated using the same model. However, soccer practitioners should consider that this finding is strictly related to the soccer team analysed in this study; therefore, other teams could show some differences between home and away games. Furthermore, these findings have practical implications for training load management during the training microcycle, where physical training does not need to be differentiated on the basis of next game location since home and away games reported the similar game-speed (RD) outputs on average. Future research may evaluate additional independent variables to verify their effect on game-speed data. Our analysis did not analyse the game-speed demands based on the score of the game, *e.g.* win vs. lose or draw, which could affect the intensity of the match (Winter & Pfeiffer, 2016). Therefore, other independent variables could be taken into consideration by sports scientists and coaches to construct potentially more informative game-speed models. Future studies could also analyse how players' physical, technical activities, players and team game speed as well as contextual variables may affect the match outcome (Konefał et al., 2020).

Previous research reported that game demands change on the basis of the players' position (Bush et al., 2015; Carling, 2013). In this study, we confirm that game-speed output assessed per moving average window changes on the basis of a player's positional grouping (Figure 3). Significantly lower RD was reported for CB compared to CF (*small*), CM (*small*) and FB (*small*). CF reported higher RD compared to WM (*small*). CM reported higher RD compared to WM (*moderate*). FB reported *higher RD* compared to WM (*small*). Additionally, this study reported a similar trend of decline in peak running intensity between players' positions as reported by previous research (Delaney et al., 2018). These findings can be of critical importance for position-specific physical training in soccer. In many cases, soccer players do not receive a specific physical training based on their game position but instead, they train together performing similar soccer drills (*e.g.*, using small-sided games) and therefore experience similar external training loads (Bianchi et al., 2019; Dello Iacono et al., 2019). This training approach could underestimate the game-speed demands for some positions, as well as overestimate the RD for some others, which could result in an inadequate quantification of training load during the weekly microcycle or mesocycle (Duthie et al., 2018; Gualtieri et al., 2020; Malone et al., 2015). This situation may be further complicated during some specific periods of the season when several competitions (*e.g.* the national cup, the national league, the international cup) are played in the same microcycle (Gualtieri et al., 2020; Morgans et al., 2018; Thorpe et al., 2015). It has already been reported that congested fixture periods represent an obstacle for players' training, injury prevention, and training load management (Dupont et al., 2010; Gualtieri et al., 2020). Therefore, the current knowledge about game-speed differences among players' positions could have an important role for sports scientists and coaches, which should consider specific player position training load demands on the basis of the findings in this study. Thus, during both congested and non-congested fixture periods, positions should be taken into consideration in order to adequately prepare specific groups within the team (Jones et al., 2019). Sport scientists and soccer coaches can modify soccer-specific drills (*e.g.* small and large sided games, as well as soccer circuits) and adapt some rules to allow higher speed intensities for specific positions (*e.g.*, FB) in order to adequately load the players (Lacome et al., 2018; Stone & Kilding, 2009).

Some limitations need to be taken into consideration when applying the results of this research in practice. Firstly, a single team of soccer players represents a relatively low sample size. However, we have considered only one club in our analysis which has made it possible to limit the confounding factors associated with different types of playing and training style, which could have affected the game-speed demands and the ecological validity of the study. Moreover, it is well known that inter-unit and inter-model variability exist between different GNSS devices (Beato, Coratella et al., 2018; Beato & De Keijzer, 2019; Thornton et al., 2019); therefore, the monitoring of only one soccer team has allowed us to use the same GNSS device throughout the season avoiding this bias. Secondly, this study analysed the game-speed demands of professional soccer players competing in the English Championship league. Therefore, the results have a great applicability for teams playing at the same professional level, but the same findings cannot be generalized to other cohorts, such as male semi-professional clubs or female professional teams. The findings reported in this study may be different if another team is analysed; therefore, future research is needed to verify if our results and game-speed models can be applied to other clubs playing at different levels and in different leagues.

Conclusions

This study presents a quantitative model describing the running intensity of English Championship soccer. It reports that male soccer players' game-speed demands are affected by the time window analysed. Higher game speed has been found analysing shorter time intervals (*e.g.* 1–2 minutes vs. 10 min). Additionally, players' positional groups have significantly different game-speed demands (*e.g.*, CM vs. WM), which should be considered during match analysis and training load periodization. This study also found that game-speed outputs are not affected by the location of the match (home vs. away); therefore, sports scientists should consider this new evidence during their performance analysis and the construction of effective training prescriptions.

The findings of this study contribute important information related to match day game-speed outputs of professional soccer and present a set of mathematical models that can be used to evaluate the game-speed demands of professional soccer players. Practitioners can use the approach and models presented in this study to approximate the typical demands of competition and implement training interventions with the aim of replicating or overloading those demands. This type of approach is particularly advantageous when performance staff are required to prepare players to compete in a competition for the first time, or who are returning from an injury or long absence. Having a general or specific game-speed model for a playing position provides a set of anchor points which can be used as objective markers in the preparation and rehabilitation of players. These markers not only consider the average demands of the game but also its most intense periods, forming a more complete profile of the physical demands required to perform in a competition such as the English Championship. Performance staff can also utilize this information as part of the long-term development of youth players who aspire to compete at this level, and intelligent training drill design can be developed to gradually expose youth players to the physical, technical and tactical demands of senior competition across a spectrum of intensities relative to game speed. Similarly, as previously stated, the practice of game-speed modelling is an effective method of assessing the relative demands of training drills in comparison to match day outputs; this provides coaches and performance staff with a novel method to use when selecting or designing training activities. Using the duration of a training drill, coaches can quickly and easily assess the running intensity relative to game demands of the same duration and express those differences in terms of a percentage value. This method provides an arguably more granular and controlled approach to managing the volume, intensity and specificity of training activities. Therefore, we conclude that game-speed modelling is a highly practical method of analysing the demands of competition and provides coaches and performance staff with key information that can be used to develop players, inform rehabilitation practices and manage the design and selection of training protocols with a high degree of control.

Disclosure statement

No potential conflict of interest was reported by the authors.

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