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Research article

Decline in Match Running Performance in Football is affected by an Increase in Game Interruptions

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Abstract
This study quantified the contribution of game interruptions to the fatigue-related declines in match running performance over the course of a football match. Using a semi-automatic multiple camera system, the running activity of 792 individual German Bundesliga performances was divided into pre-defined 15-minute intervals and subsequently analysed under two prerequisites: with (effective playing time) and without (total playing time) consideration of game interruptions. Results showed a significant decline in effective playing time over the course of a match, from 66.3% of the total playing time in the first 15 minutes to 55.9% in the final 15 minutes of a match. Under consideration of the total playing time, match running performances decreased by 24.2% on average; considering the effective playing time, they decreased on average by only 10.2%. It can, therefore, be concluded that more than half (57.9%) of the commonly reported decline in match running performance cannot be assigned to physical fatigue, but rather to an increase in game interruptions as the game progresses. In conclusion, this study demonstrated for the first time that the decline in players' match running performance during football matches is substantially amplified by a proven increase in game interruptions, indicating that there may be a tendency among practitioners to overestimate fatigue-induced performance declines.

Key words: Football, fatigue, match running performance, effective playing time.

Introduction

Over the past two decades, fatigue development in football has become one of the primary research areas in the broader field of football physiology (Bangsbo et al., 1994; Mohr et al., 2003; 2010; Reilly, 1997; Bradley et al., 2013; Waldron and Highton, 2014). Among mental and tactical factors encompassing fatigue, particular attention was paid to the element of physical fatigue (Paul et al., 2015), leading to a wealth of time–motion analyses pertaining to match running performance in top-level football (Bradley et al., 2009; Di Mascio and Bradley, 2013; Di Salvo et al., 2009; Rampinini et al., 2007; Weston et al., 2011). To evaluate physical fatigue in terms of a decline in players' match running performance, the approach taken by most studies has been to compare temporal running patterns in the early and later stages of a match. Using such segmentation methods, studies have demonstrated a decline in running performance between the first and second halves of football matches, particularly in total distance covered (TD), time spent in high intensity running (HIR) and number of sprints (Di Salvo et al., 2009; Mohr et al., 2003; Rampinini et al., 2009). Others have examined match-running performance across 15-min periods, reporting significant reductions of HIR and acceleration efforts over the course of a match (Akenhead et al., 2013; Bradley et al., 2010). A more detailed analysis on minute-by-minute observations revealed that by eight minutes into the second half the median distance per minute had already substantially decreased in comparison to the corresponding median distance in the first half (Barros et al., 2007).

To gain practice-oriented recommendations from such observations, sports scientists need to consider the work rate-specific characteristic of the sport. Football is an intermittent sport that involves frequent but brief periods of high-intensity movement, interspersed with lower intensity running (Bangsbo, 1994) and matches are usually composed of a series of play periods randomly interspersed with game stoppages, such as when the referee has called an infringement, or the ball is off the playing field (Wallace and Norton, 2014). Accordingly, a study of game interruptions in elite football showed that matches are halted on average for 38% of the total match time (Siegle and Lames, 2012). More importantly, evaluations of the time the ball is in play over predefined match periods have indicated that the duration of game interruptions increases towards the end of a match (Carling and Dupont, 2011), indicating that an increase in game interruptions towards the end of a match could have an impact on match running performance. However, only one study has analyzed football-specific match running performance while considering the effective playing time (T_{eff}), and this was based only on an entire match without consideration of fatigue development (Castellano et al., 2011). Thus, to the best of our knowledge, no study has evaluated the contribution of game interruptions to the decline in match running performance in professional football.

Therefore, the aims of this study were twofold: (1) to test whether a verifiable decrease in effective playing times occurs over the course of a match, and (2) to quantify the contribution of game interruptions to the decline in match running performance as the game progresses.

Methods

Participants and sample size

The sample comprised positional data from 51 matches of the German Bundesliga across the 2012/2013 (n = 21) and 2013/2014 (n = 30) season. Analysis included data for outfield players (goalkeepers excluded) who completed the

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full duration of the match, excluding substitutes, as their performance differs significantly from the performance of the players they replace (Carling et al., 2010). In addition, only matches with a narrow end result (one-goal difference or tie games) were considered for analysis. Based on these criteria, the match running performances of 792 players (single observations) were examined. It was a condition of players' employment that data such as those used in this study could be obtained for routine assessment of their performance during the competitive Bundesliga season. Hence, the usual ethics committee approval was not required (Winter and Maughan, 2009). All subject identifiers were removed to ensure confidentiality. This study conformed to the recommendations of the Declaration of Helsinki.

Data collection

Analysis included the official match running performance data of the Deutsche Fußball Liga GmbH, which were assessed by a computerized multiple-camera tracking system (TRACAB®, Stockholm, Sweden) operating at 25 Hz. This tracking system semi-automatically assesses the match running performance data of all players, the position of the ball, and corresponding match events (such as game stoppages), allowing the quantification of effective playing time (T_{eff}) as the total playing time (T_{tot}) minus all game stoppages such as for fouls, goals, free kicks, substitutions and injuries, i.e. the total time during the match that the ball is in play (Castellano et al., 2011).

Using a football-specific criterion measure approach pioneered by Reilly and Thomas (1976) (for a review, see Carling et al., 2005; Reilly, 2003), an independent study on the validity and reliability of the TRACAB® tracking system reported average measurement errors of 2% for measures of distance covered.

Match analysis

To investigate temporal patterns in match running performance, data were divided into six pre-defined 15-minute match periods (three per half). Periods of extra time at the end of the first and second halves were excluded from the analysis. The categorical independent variables were (i) the match period, and (ii) the method of time registration (T_{eff} vs. T_{tot}). The continuous dependent variable was the match running performance data. In accordance with previous research (Bradley et al., 2009; Carling et al., 2008; Carling and Dupont, 2011; Mohr et al., 2003), match running data were divided into the following categories: total distance, walking (0.7–7.2 km·h^{-1}), jogging (7.2–14.4 km·h^{-1}), running (14.4–19.8 km·h^{-1}), high-speed running (19.8–25.1 km·h^{-1}), and sprinting (>25.2 km·h^{-1}). Match running performance parameters calculated for the T_{eff} condition included only the performances that took place when the ball was in play, whereas the parameters calculated for the T_{tot} condition included the performance over the entire period of the match. To allow sound comparison of physical performance in both T_{eff} and T_{tot}, all distance categories were converted to a relative analysis per unit of time (m·min^{-1}).

The chosen procedure to analyse the contribution of game interruptions to the decline in match running performance consisted of the following concept: for each match period, each player's match running performance was calculated under two conditions (T_{eff} and T_{tot}). Under the assumption that T_{eff} decreases towards the end of a match, it is to be expected that the observed difference in match running performance between the two conditions (T_{eff} and T_{tot}) increases equally. Therefore, the hypothesis was tested whether the difference in match running performance between the two conditions (T_{eff} and T_{tot}) increases towards the end of a match.

Statistical analysis

A one-way analysis of variance (ANOVA) was conducted to test the hypothesis whether (i) a verifiable decrease T_{eff} occurs over the course of a match, and (ii) whether the observed difference in match running performance in the two conditions (T_{eff} and T_{tot}) increases over the course of a match. Eta-squared η^2 effect sizes were classified as small (0.01–0.05), medium (0.06–0.14) and large (>0.14), in accordance with the recommendation of Cohen (1988). Bonferroni's post hoc analyses were used when significant differences were found to compare performance parameters in the first (1'-15') and final (76'–90') match periods. Cohen's d effect sizes for Bonferroni's t-tests were classified as trivial (0-0.19), small (0.20–0.49), medium (0.50–0.79) and large (>0.80). Because preliminary analyses indicated that the distributions of match running performances were skewed, log transformation was used, which yielded normally distributed data. Statistical significance was set at $p < .05$. Data are presented as the mean ± standard deviation (SD). Statistical analyses were performed using the software package SPSS version 23.0, (IBM Corp., Armonk, NY, USA).

Results

Effective playing time

There was a statistically significant difference in T_{eff} between the six match periods as determined by one-way ANOVA [$F(5,480) = 9.844$, $p < 0.001$, $\eta^2 = 0.134$]. Pairwise comparisons of the means using Bonferroni's post-hoc procedure indicated that T_{eff} was significantly lower ($p < 0.001$, $d = 1.12$) in the last match period (33.5 ± 4.9 s·min^{-1}, 55.9% of T_{tot}) compared to the first match period (39.8 ± 6.3 s·min^{-1}, 66.3% of T_{tot}). There was no significant difference between the second, third, and fourth match period ($p = 0.242$). These results affirm the hypothesis that length and frequency of game interruptions do, in fact, increase towards the end of a match, therefore leading to a significant reduction of T_{eff} (see Figure 1).

Match running performance

A one-way ANOVA was conducted to compare the effect of the progressive match period on the difference in match running performance between the two conditions (T_{eff} and T_{tot}). There was a significant effect of the match period on difference in total distance covered per player [$F(5, 9204) = 75.7$, $p < 0.001$, $\eta^2 = 0.08$]. Bonferroni's post hoc comparisons indicated that the mean difference in the first (50.6 ± 18.0 m·sec^{-1}) match period was significantly lower than

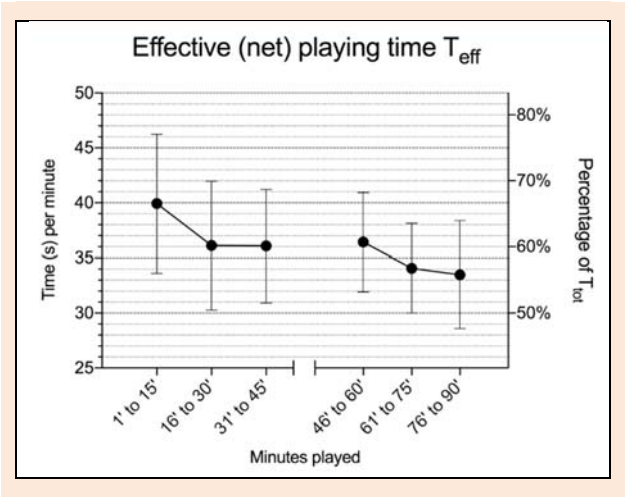

Figure 1. Development of effective playing time T_{eff} over the course of a match. Data were obtained for six 15-min periods of match-play (presented as means and standard deviation).

the difference in the last (61.9 ± 14.2 m·sec^{-1}) match period [t(767) = 15.8, p < 0.001, d = 0.69] (see Table 1 and Figure 2). Under consideration of T_{tot}, total distance decreased from 99.1 ± 16.0 m·min^{-1} during the first match period to 78.0±13.8 m·min^{-1} during the final match period (p < 0.001, d = 1.41), corresponding to a decline of 21.2%. In comparison, under consideration of T_{eff}, total distance decreased from 149.7 ± 14.9 m·min^{-1} during the first match period to 139.8 ± 16.8 m·min^{-1} during the last match period (p < 0.001, d = 0.62), corresponding to a decline of merely 6.6 %. Comparable results were found for the jogging, running, high- speed running, and sprinting category (see Table 1 and 2). It should be noted, however, that the amplifying effect decreases with increasing running speeds, expressed in lower effect sizes in higher speed categories.

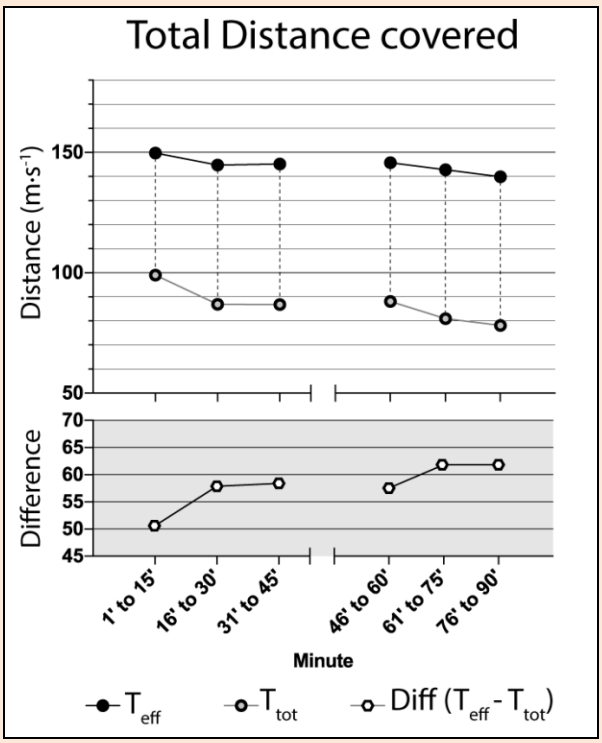

Figure 2. Development of match running performance over the course of a match (using the example of total distance covered).

Table 1. Results from one-way ANOVA and Bonferroni's post hoc procedure showing the effect of the match period on the difference in the respective performance category between T_{eff} and T_{tot}.

	ANOVA of Differences			Bonferroni's post hoc procedure				
	F	< p	η²	1' to 15'	76' to 90'	Change	<p	d
Total Distance	75.7	.001	.08	50.6 ± 18.0	61.9 ± 14.2	22.2%	.001	.69
Walking	225.6	.001	.20	10.7 ± 3.5	15.7 ± 3.6	48.1%	.001	1.45
Jogging	32.5	.001	.03	24.1 ± 8.5	27.9 ± 7.6	15.8%	.001	.47
Running	16.5	.001	.02	10.7 ± 5.7	12.1 ± 5.2	13.5%	.001	.27
High Speed Running	21.2	.001	.02	3.9 ± 2.7	4.6 ± 2.8	18.0%	.001	.26
Sprinting	7.9	.001	.01	1.4 ± 1.5	1.7 ± 1.7	22.8%	.006	.20

Table 2. Descriptive statistics: difference in match running performance (m·min^{-1}) between the first (minute 1' to 15') and last (minute 76' to 90') match period.

	Effective playing time T_{eff}					Total playing time T_{tot}				
	1' to 15'	76' to 90'	Change	< p	n	1' to 15'	76' to 90'	Change	< p	n
Total Distance	149.7 ± 14.9	139.8 ± 16.8	-6.6%	.001	.62	99.1 ± 16.0	78.1 ± 13.8	-21.2%	.001	1.41
Walking	32.3 ± 6.3	36.0 ± 6.6	11.4%	.001	.57	21.6 ± 6.0	20.2 ± 5.1	-6.7%	.001	.25
Jogging	71.3 ± 13.0	62.9 ± 14.1	-11.9%	.001	.62	47.4 ± 11.2	35.2 ± 9.5	-25.7%	.001	1.17
Running	30.5 ± 10.4	26.8 ± 9.6	-12.0%	.001	.37	20.0 ± 6.6	14.8 ± 5.3	-25.6%	.001	.87
High speed running	11.1 ± 5.2	10.3 ± 5.3	-7.1%	.001	.15	7.2 ± 3.2	5.7 ± 2.8	-20.8%	.001	.50
Sprinting	3.3 ± 3.2	2.8 ± 3.1	-13.6%	.003	.16	2.1 ± 1.9	1.5 ± 1.6	-27.6%	.001	.34

Discussion

Based on the assumption that game interruptions increase towards the end of a football match, this study examined the resulting effects on the frequently reported decline in match running performance in professional football. In contrast to previous studies focusing on the decline of match running performance, this study compared the magnitude of the observed declines - considering both effective and total playing times.

As a preliminary result, this study confirms that an increase in game interruption time does, in fact, lead to a 10.4% decline in effective ball-in-play time towards the end of a match. Although changes of T_{eff} over the course of a match have rarely been documented, these findings are in good accordance with previous research by Carling and

Dupont (2011), who reported an overall decline of eight percentage points of T_{eff} in French Ligue 1 matches (from 66% T_{eff} in the first period (0–5 min) to 58% in the last period (85–90 min)).

Direct comparison of the decline in match running performance with previous research is only possible to a limited extent, as only few studies have provided detailed results of individual performance indicators in each respective match period. In addition, different timeframes (1', 5', 15' or 45' periods) as well as different definitions of speed categories have been chosen for investigating match related fatigue patterns.

Under the T_{tot} condition, total distance decreased by 21.2% over the course of a match, whereas a similar study reported a 14.3% decline of total distance in UK Premier League players between the first and last 5-min period (Weston et al., 2011). In another study, Carling and Dupont (2011) found that high-intensity running distance (comprising high speed running and sprinting distance) covered by French Ligue 1 midfielders decreased by 24.2% between the first and last 5-min period. Similarly, Bradley et al. (2010) found that Premier League players covered 17.8% less high-intensity running distance in the last 15-min period compared to the first. Players in the present study covered 20.8% less high-speed running distance and 27.6% less sprinting distance in the same period. It could, therefore, be assumed that the results of the present study are generally consistent with those of previous research on match-related fatigue, as far as T_{tot}-based analyses are concerned. However, a unique element of this investigation was the ability to differentiate between performance declines based on both T_{eff} and T_{tot}.

As shown in Table 2, walking distance increased by 11.4% under the T_{eff} condition. Contrastingly, walking distance decreased by 6.7% under the T_{tot} condition. In consequence, higher gains of walking distance under the T_{eff} condition could indicate fatigue-related gains in walking distance during active gameplay. The decrease of walking distance under the T_{tot} condition, by contrast, probably results from an increase of game interruptions, leading to more standing phases, and thus also less distance covered in total.

The key finding of this study was that all other investigated performance indicators decreased by significantly less when game interruptions were considered. This was evident in both percentage declines of match running performance and a significant increase of the difference in match running performance between the two conditions (T_{eff} and T_{tot}). With respect to the total playing time, jogging, running, high intensity running, and sprinting distance decreased by 24.2% on average, whereas they decreased by only 10.2% with respect to the effective playing time. In other terms, the reported decline in match running performance under T_{tot} is more than twice as high as under the T_{eff} condition, indicating that approximately 57.9% of the decline in match running performance observed for T_{tot} is caused by an increase of game interruptions and thus cannot be related to physical fatigue.

It is noteworthy, however, that there were notable effect size differences for the different performance indicators. Specifically, smaller effect sizes were found in higher speed categories (see Table 1). Collectively, these results demonstrate that the influence of game interruptions on the decline in match running performance decreases with increasing movement intensity. Only small or even no effect sizes were found in the categories with a predominantly high-intensity nature (high intensity running and sprinting). In contrast, medium effect sizes were present in the medium-intensity categories such as total distance, walking, jogging and running distance. This may be explained by the predominantly intermittent nature of activity patterns of football, with players switching between brief bouts of high-intensity running and longer periods of low-intensity exercise (Rampinini et al., 2007). Thus, a majority of the total distance is covered at low or medium intensities, resulting in strong effect sizes for the associated movement categories.

However, it can be presumed that the occurrence of high-intensity movement is highly dependent on a variety of randomly occurring factors, such as sudden opportunities that require short and intense efforts to gain an advantage over the opponents, which can occur at any time during the match. It can be concluded that, regardless of physical fatigue towards the end of a match, players are able to perform at high intensity at any time, whenever necessary.

From a statistical perspective, the magnitude of match-related fatigue can be quantified more effectively for low and medium intensity categories. The often-described decrease in high-intensity movement categories (Bradley et al., 2009; 2010; Mohr et al., 2003) appears to be attenuated considerably when considering the effective playing time.

The limitations of this study include a lack of control for position-specific subdivisions of players, seasonal variation, match importance, and international differences. The observed patterns may, therefore, be a reflection of this specific league. In particular, match status (winning, drawing or losing) is a factor that has attracted increasing attention in the scientific literature, with some studies suggesting that the current score of a match has a considerable influence on match-related performance outcomes (Taylor et al., 2008). Bradley and Noakes (2013) demonstrated that players were able to maintain their high-intensity running performance in the second half of matches in which they were losing heavily, but this was not evident in matches where they were well ahead in score; this, in turn, could indicate players had a pacing strategy in an attempt to avoid unnecessary fatigue during clear results (Edwards and Noakes, 2009).

It should further be mentioned that concerns have been expressed about the attempted to quantify accumulated fatigue by comparing match-running activity during the first game period with that of the final game period (Carling, 2013). Reasons for such concerns are based on the frantic nature of the very first phases of gameplay in which teams show engagement to register their presence with the opposition (Bangsbo et al., 1991). Such purely psychological factors could, therefore, be mistakenly interpreted as physical fatigue. Overall, physical performance

in football is influenced by a great number of factors, all of which can hardly be considered collectively (Carling, 2013). It seems likely that no single study would be able to comprehensively measure and control for all extraneous influences (Paul et al., 2015). Thus, caution is needed before attributing our findings to the nature of football. Finally, future work could investigate the influence of the effective playing time on the proven decline in high-intensity running immediately after the most intense 5-min period (Bradley et al., 2009).

Nevertheless, the intention of this study was to provide a basic overview of the influence of game interruptions on the physical performance of football players, with a focus on the decline in running performance. For sports scientists and coaches, knowledge of fatigue patterns considering the effective playing time provides a more accurate representation of competitive physical demands, and this, in turn, can be applied in training to develop practice drills that are more closely tailored to actual match requirements (Castellano et al., 2011).

Conclusion

This study demonstrated for the first time that the decline in players' match running performance during football matches is substantially amplified by a proven increase in game interruptions as the game progresses, indicating that there may be a tendency among practitioners to overestimate fatigue-induced performance declines. Previous studies with the objective to quantify a reduction in match running performance should, therefore, be interpreted with caution, as game interruptions are often omitted from these studies.

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Key points

- The effective ball-in-play time decreases from 66.3% of the total playing time in the first 15 minutes to 55.9% in the last 15 minutes of a match.
- Under consideration of the absolute playing time, match running performances decreased by 24.2% on average, whereas they decreased by only 10.2% under consideration of the effective playing time.
- Accordingly, 57.9% of the commonly reported decline in match running performance cannot be assigned to physical fatigue, but rather to an increase in game interruptions as the game progresses.

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