Time-motion analysis of work-rate in English FA Premier League soccer

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Abstract

This study used time-motion analysis to characterise the intermittent nature of professional soccer competition. The activity of the mean defender, midfielder and forward covered by Sky Digital's PlayerCam facility in 35 English FA Premier League matches were compared. During a 15 minute observation period, players performed 30.6 ± 3.5 bursts of high intensity including 14.1 ± 2.3 bursts of under 2 s and 3.0 ± 0.2 bursts of 6 s or longer. There was no significant difference between the duration of the average burst performed by defenders, midfielders or forwards ($P>0.05$). Midfielders had a significantly shorter recovery between bursts than defenders ($P<0.01$). These results suggest that there is variation in the duration of high intensity bursts as well as low intensity recoveries in professional soccer that should be considered when designing conditioning elements of players' training programmes. Furthermore, the amount of recovery between high intensity bursts is influenced by playing position.

Key words: Soccer, positional role, work-rate, activity profile.

1 Introduction

Time-motion analysis studies of soccer have compared the activity profiles of different positional roles in terms of the distribution of match time among different activities (Bangsbo et al., 1991) as well as distance covered by players (Reilly & Thomas, 1976; Withers et al., 1982). Results of these studies express average work to rest ratio observed during the match. Values for the duration of the average burst of high intensity activity range from 2.5 s (O'Donoghue et al., 2001) to 4 s (Mayhew & Wenger, 1985). Work to rest ratios of between 1 : 7 and 1 : 10 are typical in soccer (O'Donoghue et al., 2001). However, the work to rest ratio is not uniform throughout a match with bursts of high intensity activity ranging from short one-touch ball contact to rare bursts of over 10 s (O'Donoghue et al., 2001). Similarly, recovery periods may range from a short break between two bursts of high intensity activity to over a minute during prolonged stoppages in the game. Knowledge of the range of durations for high intensity bursts and low intensity recovery periods is important to the understanding of the intermittent nature of soccer. The primary purpose of the current study was to describe the intermittent nature of English FA Premier League soccer in terms of the duration of high intensity bursts and low intensity recovery periods. A further aim of the investigation was to compare the work rate of defenders, midfielders and forwards. New information provided for coaches from the study is the range of durations of high intensity bursts as well as the range of durations of low intensity recovery periods.

2 Methods

2.1 Players and Matches

Fifty-two matches were observed using Sky Television's PlayerCam facility. This facility follows six players for approximately 15 minutes each during the match rather than following the ball. It is, therefore, ideal for time-motion analysis of the on-field activity of players including off-the-ball movement. A special purpose computerised work-rate analysis system allowed the user to record work and recovery periods for the six players covered by PlayerCam during each match.

2.2 Computerised work-rate analysis

It was decided to record only two broad activity classes ("work" and "rest") instead of a larger classification of movements because:

- Each player was only being observed for 15 minutes and recording individual movements such as standing, walking, jogging and running might lead to an unrepresentative measurement for those activities for individual players.
- Many time-motion studies classify movements as high or low intensity activities and the key results reported are the proportion of time spent performing high intensity activity and the work to rest ratio.

"Work" was defined as activity performed by the player that was perceived to be of a high intensity by the observer. "Work" would typically include running, sprinting, shuffling movements used to track opponents as well as on-the-spot shuffling movement. All contact with the ball or competing for the ball while the ball was in-play was classified as "work". The assumption that all ball contact was high intensity exercise was made because movement with the ball elevates heart rate response above that when the player is not mastering the ball (Reilly & Ball, 1984). All other activity was recorded as "rest". "Rest" would typically include standing, sitting, walking, jogging and lying in a prone position. The computerised system used the F1 function key to record the beginning of each work period and the F2 key to record the beginning of each rest period. The F10 key was used to indicate that PlayerCam had finished observing the current player.

The system summarised the sequence of timed work and rest periods entered for each player using the following variables:

- The number of high intensity bursts performed.
- The average duration of high intensity bursts as well as the average duration of low intensity recovery periods.

- The number of high intensity bursts of under 2 s, 2 s to under 4 s, 4 s to under 6 s, 6 s to under 8 s, 8 s to under 10 s, 10 s to under 12 s and 12 s or greater.
- The number of low intensity recovery periods of under 2 s, 2 s to under 4 s, 4 s to under 8 s, 8 s to under 12 s, 12 s to under 20 s, 20 s to under 45 s, 45 s to under 90 s and 90 s or greater.
- The percentage of observation time spent performing high intensity work and low intensity recovery activity.

The durations of high intensity bursts and low intensity recovery periods were chosen after considering PlayerCam data from previous research that revealed that most bursts of high intensity activity were under 10 seconds while there was a wider range of recovery periods (O'Donoghue & Parker, 2001). The recovery periods analysed were those between bursts as the full duration of the recovery period that followed the final burst performed would not be recorded.

2.3 Objectivity

Table 1. Results of the inter-observer objectivity study.

(a) Player 1

Observer 1	Observer 2		
	Rest	Work	Total
Rest	833.1	16.9	849.9
Work	19.0	34.4	53.4
Total	852.1	51.2	903.3

$p_o = 0.960$, $p_e = 0.891$, $\kappa = 0.636$

(b) Player 2

Observer 1	Observer 2		
	Rest	Work	Total
Rest	822.5	36.3	858.8
Work	40.2	18.3	58.5
Total	862.7	54.6	917.2

$p_o = 0.917$, $p_e = 0.884$, $\kappa = 0.279$

(c) Player 3

Observer 1	Observer 2		
	Rest	Work	Total
Rest	816.7	11.2	827.9
Work	26.9	56.9	83.7
Total	843.6	68.1	911.6

$p_o = 0.958$, $p_e = 0.847$, $\kappa = 0.727$

(d) Player 4

Observer 1	Observer 2		
	Rest	Work	Total
Rest	834.2	24.8	859.1
Work	32.2	59.4	91.6
Total	866.4	840.2	950.6

$p_o = 0.940$, $p_e = 0.832$, $\kappa = 0.642$

(e) Player 5

Observer 1	Observer 2		
	Rest	Work	Total
Rest	740.2	13.2	753.4
Work	19.2	73.4	92.6
Total	759.4	86.6	846.0

$p_o = 0.962$, $p_e = 0.811$, $\kappa = 0.798$

(f) Player 6

Observer 1	Observer 2		
	Rest	Work	Total
Rest	957.4	13.7	971.1
Work	16.0	78.5	94.5
Total	973.4	92.2	1065.6

$p_o = 0.972$, $p_e = 0.840$, $\kappa = 0.825$

The cross-tabulated values are the times (s) where each activity class was recorded by each observer.

An inter-observer study of 6 players from a single match was undertaken to establish the objectivity of the method. For each player, the two sequences of timed movements were compared to determine the proportion of time where the two independent observers agreed on the activity being performed by the player, p_o. With only two defined movement classes, the probability of agreement by chance, p_e, needed to be addressed using the kappa statistic, κ. Tables 1(a) to 1(f) show the results of the inter-observer study. The strength of agreement indicated by the κ values were interpreted as fair for 1 player, good for 4 players and very good for 1 player (Altman, 1991).

Detailed examination of the data recorded by the two observers showed that the weaker κ values resulted from some shuffling movements only being recorded as high intensity activity by one observer. Another source of disagreement was due to high intensity bursts being recorded at slightly different start and end times between the two observers. Such phase differences reduced inter-observer agreement during the recording of very short bursts of high intensity activity.

2.4 Reliability

As the observer was part of the data collection method, it was also necessary to undertake an intra-observer reliability study using 6 players from a single match, the results of which are shown in tables 2(a) to 2(f). The interpretation of κ for the intra-observer reliability study was a good strength of agreement for 3 players and a very good strength of agreement for the other 3 Players (Altman, 1991).

2.5 Data analysis

Table 2. Results of the intra-observer reliability study.

(a) Player 1

Observation 1	Observation 2		
	Rest	Work	Total
Rest	843.5	10.6	854.1
Work	9.7	40.6	50.3
Total	853.2	51.2	904.4

$p_o = 0.978$, $p_e = 0.894$, $\kappa = 0.788$

(b) Player 2

Observation 1	Observation 2		
	Rest	Work	Total
Rest	857.8	14.4	872.3
Work	4.8	40.1	45.0
Total	862.7	54.6	917.2

$p_o = 0.979$, $p_e = 0.897$, $\kappa = 0.795$

(c) Player 3

Observation 1	Observation 2		
	Rest	Work	Total
Rest	822.4	19.0	841.4
Work	21.2	49.1	70.3
Total	843.6	68.1	911.6

$p_o = 0.956$, $p_e = 0.860$, $\kappa = 0.686$

(d) Player 4

Observation 1	Observation 2		
	Rest	Work	Total
Rest	853.4	15.9	869.3
Work	12.8	68.4	81.2
Total	866.2	84.2	950.5

$p_o = 0.970$, $p_e = 0.841$, $\kappa = 0.810$

(e) Player 5

Observation 1	Observation 2		
	Rest	Work	Total
Rest	755.9	19.2	775.1
Work	3.9	67.4	71.3
Total	759.8	86.6	846.4

$p_o = 0.973$, $p_e = 0.831$, $\kappa = 0.839$

(f) Player 6

Observation 1	Observation 2		
	Rest	Work	Total
Rest	966.1	14.8	980.9
Work	7.6	77.5	85.1
Total	973.7	92.2	1066.0

$p_o = 0.979$, $p_e = 0.847$, $\kappa = 0.862$

The cross-tabulated values are the times (s) where each activ ity class was recorded during each observation.

The player performances analysed were not independent because the matches used contained data from more than one player. It was, therefore, decided to make the match rather than player the subject of statistical tests. Mean values were determined for the frequency, duration and percentage of match time (%time) for each movement class for the defender, midfielder and forward in each match. Some players were excluded as their role could not be accurately classified as defender, midfielder or forward. The PlayerCam facility followed at least one player of each position in only 35 of the 52 matches and, therefore, only these 35 matches were included in the analysis. Over the 35 matches used, there was a chi squared test of independence revealed that significantly different profiles of positions were recorded between the six 15 minute periods ($\chi^2_{10} = 41.2$, $P < 0.001$) with more forwards than expected being followed by PlayerCam during the first 15 minutes of the match. However, a repeated measures Analysis of Variances (ANOVA) did not reveal a significant influence of observation period on the percentage of time spent performing work ($F(5,170) = 0.8$, $P > 0.05$). Therefore, match time was deemed not to have an influence on the data.

A series of repeated measures ANOVA tests including position as a within-match effect was used to determine the influence of position on the frequency of high intensity bursts, the duration of the average burst and average recovery period as well as the percentage time spent performing high intensity activity. Where position had a significant influence, Bonferroni adjusted post hoc tests were used to compare pairs of positions. The frequency of high intensity bursts of different durations as well as the frequency of low intensity recovery periods of different durations were analysed using two-way repeated measures ANOVAs that included both position and length of burst (or recovery) as within-match effects. A significant interaction of position and length of burst (or recovery) on the number of bursts (or recoveries) would indicate a different profile of bursts (or recoveries) between positions. Where a repeated measures ANOVA produced a significant result but the assumption of Sphericity was violated, the Greenhouse-Geisser (GG) adjustment was applied to the results, reporting the epsilon value (ε) used to adjust the degrees of freedom.

3 Results

Mauchly's test revealed that Sphericity could be assumed for each of the dependent variables used to compare the three positions in table 3 (Mauchly's $W \geq 0.835$, $\chi^2_2 \leq 5.9$, $P>0.05$). Position had no significant influence on the duration of the average high intensity burst performed, which was identical for midfielders and forwards. However, midfielders had a significantly lower average recovery between bursts than defenders resulting in them performing a significantly greater number of bursts than defenders. Therefore, midfielders spent a significantly greater percentage of time performing work than defenders.

Table 3. Summary of analysis of the effect of position on activity profile (mean±SD).

Measure	Defender	Midfielder	Forward	F(2,68)
%time spent performing work	9.2±2.4 &&	11.0±2.5	10.4±1.6	7.7**
Number of bursts	28.4±6.4 &	32.1±6.0	31.4±4.8	4.3*
Duration of mean high intensity burst (s)	3.1±0.5	3.2±0.4	3.2±0.4	1.3
Duration of mean low intensity recovery (s)	31.9±7.9 &&	27.1±5.4	28.2±4.3	6.5**

The significance of the F-ratio of each repeated measures ANOVA is indicated (* P<0.05, ** P<0.01). Bonferroni adjusted post hoc tests were used to compare positions in the event of a significant F-ratio revealing significant differences between defenders and midfielders (& P<0.05, && P<0.01).

Table 4 shows the number of high intensity bursts of different durations performed by the three different positions. The interaction of position and length of burst had no significant influence on the number of bursts ($F(12,408) = 1.7$, $P>0.05$). Table 5 shows the number of recovery periods of different durations for the three positions. The interaction of position and duration of recovery period had a significant influence on the number of recoveries (GG: $\varepsilon = 0.470$, $F(14,476) = 3.9$, $P<0.01$). Midfielders had the most recoveries of under 20 s, forwards had the most recoveries of 20 s to under 45 s while defenders had the most recoveries of 45 s and longer.

Table 4. Frequency of high intensity bursts of different durations (mean±SD).

Duration of burst	Defender	Midfielder	Forward
Under 2 s	13.2±3.9	14.6±3.5	14.4±3.0
2 s to under 4 s	9.1±2.5	10.3±2.4	10.1±1.9
4 s to under 6 s	3.3±0.9	3.9±1.1	3.9±1.2
6 s to under 8 s	1.9±1.5	2.0±1.5	1.5±0.9
8 s to under 10 s	0.5±0.6	0.7±0.5	0.7±0.4
10 s to under 12 s	0.2±0.4	0.4±0.4	0.5±0.6
12 s or greater	0.1±0.3	0.2±0.4	0.2±0.3
Total	28.4±6.4	32.1±6.0	31.4±4.8

Table 5. Frequency of low intensity recoveries of different durations (mean±SD).

Duration of recovery	Defender	Midfielder	Forward
Under 2 s	1.5±0.8	2.1±1.2	2.0±1.1
2 s to under 4 s	1.7±0.9	2.2±1.4	2.1±1.3
4 s to under 8 s	2.8±1.7	3.6±1.8	2.8±1.2
8 s to under 12 s	3.6±2.1	4.4±2.5	4.3±1.9
12 s to under 20 s	5.0±2.2	6.4±2.3	5.8±1.7
20 s to under 45 s	6.2±1.7	6.8±1.3	7.6±1.5
45 s to under 90 s	5.1±1.5	4.7±1.2	5.0±1.1
90 s or greater	1.4±0.8	0.9±0.6	0.9±0.7
Total	27.4±6.4	31.1±6.0	30.4±4.8

4 Discussion

The results provide evidence that professional soccer involves intermittent high intensity exercise with over 98% of high intensity bursts being under 10 s in duration. This is consistent with the findings of other time-motion investigations of soccer that have found high intensity bursts to average 2.5 s to 4 s (Bangsbo et al., 1991; Mayhew & Wenger, 1985; O'Donoghue et al., 2001). Midfielders were found to spend a significantly greater percentage of time performing high intensity activity than defenders which partially supports previous research that shows midfielders to cover a greater distance during soccer competition than defenders (Bangsbo, 1994; Reilly & Thomas, 1976; Withers et al., 1982). However, these previous investigations also found that midfielders covered a greater distance than forwards.

It can be assumed that aerobic sources contribute to the energy required during the 90% of the match spent performing low intensity activity such as standing, walking and jogging. Anaerobic sources contribute a minor amount of the total energy required during soccer competition, but anaerobic energy is very important during high intensity bursts (Bangsbo, 1997). The duration of high intensity bursts varies with 46% of bursts taking less than 2 s and 10% of bursts taking 10 s or longer. The range of bursts performed during soccer competition has implications for the sources of energy utilised during high intensity activity. Degradation of muscle creatine phosphate (CP) and stored muscle adenosine triphosphate (ATP) provides most of the energy for short high intensity bursts performed in soccer (Bangsbo, 1997). Glycolytic and aerobic sources have been shown to contribute to the energy required during a Wingate test after the first 5s of exercise (Smith & Hill, 1991). Aerobic sources have been shown to provide some of the energy for repeated sprints performed on cycle ergometer equipment (Bogdanis et al., 1996). Scaling the results of the current study up from the 15 minute observation period used to 90 minutes suggests that the average outfield player performs 18 bursts of 10 s or more that may derive energy from both aerobic and anaerobic sources.

There is also a range of recovery periods between bursts of high intensity activity with 57% of recoveries taking less than 20 s and 3.5% of recoveries lasting 90 s or longer. The range of recoveries between bursts may have implications for the energy systems that are utilised during high intensity bursts. Previous research has shown that blood lactate accumulation and performance decrements over five 6 s maximal sprint bouts performed on cycle-ergometer equipment were greater when a recovery of 30 s was taken between bouts than when the recovery was 60 s (Wootton & Williams, 1983). Furthermore, muscle CP may not be sufficiently replenished after recovery periods of under 45 s (Balsom et al., 1992).

5 Conclusions

The current study has provided new information for the soccer coach by looking at the range of high intensity bursts and low intensity recovery periods that occur during competition rather than using averaged values. The results show that English Premier League soccer players perform bursts of high intensity activity of a range of durations. Furthermore, there is a range of recovery periods that follow these bursts of high intensity activity. The profile of high intensity bursts performed is similar between the different playing positions. However, there are significantly different profiles of recoveries taken by players of different positions with midfielders tending to take more shorter recoveries while defenders take more longer recoveries. It is therefore recommended that the full range of bursts performed and the variation in recovery periods for players of different positions are taken into consideration when designing the conditioning elements of players training programmes.

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