Re-examination of the post half-time reduction in soccer work-rate

Running Head: Post half-time soccer work-rate

Abstract

Objectives: To re-examine the work-rate of soccer players immediately after a passive half-time interval (HT) with an alternative approach to data reduction and statistical contrasts. **Design:** Time-motion analysis data (5 Hz GPS), were collected from 20 elite youth players (Age: 17 ± 1 yrs) during 21 competitive league fixtures (5 ± 3 matches per player). **Methods:** Physical performances were categorised into total distance covered (TD), total low-speed running (LSR: 0-14.9 km·h^{-1}) and total high-speed running (HSR: 15.0-35.0 km·h^{-1}). These dependent variables were subsequently time averaged into pre-determined periods of 5-, 15- and 45-minutes duration, and expressed in relative (m·min^{-1}) terms to allow direct comparisons between match periods of different lengths. During the 15-min HT players were passive (seated rest). **Results:** There was a large reduction in relative TD (effect size [ES] - standardised mean difference - 1.85), LSR (ES -1.74) and HSR (ES -1.37) during the opening 5-min phase of the second half (46-50 min) when compared to the first half mean (0-45 min). When comparing the 51-55 and 56-60-min periods, effect sizes were trivial for relative TD (ES -0.13; -0.04), LSR (ES -0.10; -0.11) and small/ trivial for HSR (-0.39; 0.11). **Conclusions:** Using a more robust analytical approach, the findings of this study support and extend previous research demonstrating that players work-rate was markedly lower in the first 5-min after a passive HT, although we observed this phenomenon to be transient in nature. Time-motion analysts might re-consider their data reduction methods and comparators to distinguish within-match player work-rate trends.

Key Words: soccer, GPS, elite youth players, work-rate, half-time, magnitude of effect**Re-examination of the post half-time reduction in soccer work-rate**

Introduction

The 15-min half-time interval (HT) in professional soccer is typically a passive period in which players engage in tactical briefings, rehydrate, and where necessary receive medical attention. A growing body of evidence has demonstrated reduced high-speed running (HSR) activities immediately after the half-time interval, when compared to the opening 5- or 15-min period of the first half.[1,2,3] This decrement in physical performance has been largely attributed to the role of muscle temperature, with decrements of 1.5-2.0°C recorded following a passive HT, which have been associated with performance reductions in powerful soccer-specific actions[4,5] However, the reduced work-rate observed in soccer match-play may represent a statistical artefact, rather than any physiological impairment.

As motion analysis technology and data processing systems have evolved, researchers have been able to measure within-match physical performance by categorising time-motion data into pre-determined periods. Originally, between-half (45-min) comparisons were made,[6] and more recently it has become commonplace to compare the 15-min periods to make inferences regarding cumulative player fatigue.[1,2] Furthermore, contemporary studies have identified the 'temporary fatigue' phenomenon in elite-level soccer match-play, by using pre-determined 5-min periods.[1,2] To our knowledge, the arbitrary sampling frequencies adopted previously have not been rationalised, but are convenient divisors of a 90-min match.

A post-HT decrement in HSR is observed when comparing the opening 15-min periods of each half for elite players[1,3] and match referees.[3,7] However, drawing conclusions about sub-optimal preparation as a consequence of a passive HT should be made with caution. Firstly, the sampling of data over a 15-min period is considered inadequate to monitor the intricacies of the work-rate pattern.[8,9] This was demonstrated by Mohr et al.[2] who observed a decreased HSR distance in the first 5-min of the second half, compared to the corresponding phase of the first half, yet this difference was not observed in the 6-10 min period. Secondly, this initial match period may not provide an appropriate reference point against which comparisons are drawn, since the first few minutes of match-play are typically frantic in nature and consequently the tempo is at its most intense.[8,10] Thirdly, studies reporting lower physical match performances at the start of the second half have relied on null hypothesis testing. Yet in sports performance research it is not whether there is an effect, but how big the effect is and use of the P value alone provides no information about the direction or size of the effect or the range of feasible values.[11]

Therefore, the purpose of the current study was to re-examine the work-rate of players after a passive half-time interval by 1) using an alternative pre-determined match period as the criterion, 2) using 5-min segments to analyse the players' physical performances post-HT, and 3) utilising analysis techniques that express, both quantitatively and qualitatively, the magnitude of the effect. We hypothesised that our alternative analytical approach would provide a more sensitive and robust evaluation of the post-HT decrement in soccer work-rate, which may have implications for in-game player support strategies.

Methods

Twenty outfield players (Age: 17 ± 1 yrs; Height: 1.81 ± 0.05 m; Body Mass: 74.5 ± 7.4 kg; VO_{2max}: 61 ± 6 ml•kg^{-1}•min^{-1}) that represented an English Championship youth team (Under 18's) were used in this study. This sample included 4 wide defenders, 4 central defenders, 3 central midfielders, 3 wide midfielders, and 6 strikers. Each player was post-adolescent with an average of 3.2 (± 0.4) years after peak height velocity, as calculated according to Mirwald and colleagues.[12] Players trained on a 'full-time' professional basis for 13.5 hrs per week, which included 7 soccer training sessions, 2 strength training sessions, 2-3 conditioning sessions, and one competitive fixture each week. The players were unaware of the aims of the study, which had ethical clearance from the departmental committee, and obtained written and verbal consent prior to participation, in accordance with the principles outlined in the Helsinki Declaration.

The physical match data were collected from 21 competitive 'home' and 'away' league fixtures during the 2008/09 and 2009/10 seasons (giving a total of 111 match observations). Players wore a 5 Hz global positioning system (GPS; MinimaxX, Catapult Innovations, Canberra, ACT, Australia) which was harnessed between the scapulae in a customised undergarment to reduce movement artefact.

Recent work investigating the performance of 5 Hz GPS technology has found it to be reliable (CV = 2 - 5%) and valid (SEE = 1 - 2%) for measurement of total distance in soccer-specific activity.[13] Additionally, 5 Hz GPS can be used to measure the cumulative distance of prolonged high-intensity bouts of multi-directional soccer activity with both good reliability (CV = 3.5%) and validity (SEE = 1.5%).[13] Although recent research has shown only moderate agreement (r = .54) between 5 Hz GPS and a semi-automated image tracking system,[14] validity testing of image-tracking systems has not been subject to the same experimental rigour that has been applied to GPS, and as such a gold-standard measure of work-rate in soccer match-play is absent.

Players wore the same GPS unit in each game to avoid between-unit measurement error and data analysis was performed post-match. Injury time was excluded in this study, as were any incidences where the player did not complete the full game or changed tactical position during match-play. In accordance with manufacturers instructions, match cases were only included if the GPS unit was detected by a minimum of 6 satellites throughout.

Prior to the start of the match, the players participated in a standardised 25-min warm-up which included light-jogging, dynamic stretching, technical drills and repeated high-intensity exercises. On completion of the pre-match warm-up, the coach provided final tactical and motivational instructions in the dressing rooms during a 10-min interval immediately prior to kick-off. To avoid any interference with the satellite signal the GPS units were removed and left pitch-side during the 15-min HT interval whilst the players routinely returned to the changing rooms. The interval was characterised by passive (seated) rest and *ad libitum* fluid replenishment, whilst receiving technical information from the coaching staff. Where any of these outlined procedures were not adhered to, due to facility or situational factors, the data were excluded from the current study.

The distances covered by the players were categorised into arbitrary velocity bands, which included total distance covered (TD), total low-speed running (LSR: 0-14.9 $km \cdot h^{-1}$) and high-speed running (HSR; 15.0-35.0 $km \cdot h^{-1}$). We computed the mean for each variable from the set of repeat matches for each player (5 ± 3 matches per player). The HSR inception was set at 15 $km \cdot h^{-1}$ as recommended in the absence of individualised threshold prescription.[15] However, we did not consider further sub-categorising the velocity data due to the player-dependent velocities of transitions between movement patterns,[16] and because sprinting reliability and validity in discreet bouts with 5 HZ GPS is questionable[13]. Based on peak speed assessments during pilot work on this sample population, we set an upper-limit of 35.0 $km \cdot h^{-1}$ for HSR, to arrest non-physiological running speed values reported in other studies using this technology.[14]

The distances covered by the players were also categorised by pre-determined periods of 5, 15 and 45 min duration and are expressed in relative ($m \cdot min^{-1}$) terms to enable direct comparisons of player work-rate between pre-determined match periods of different lengths.

The post HT work-rate was examined by comparing the relative mean distance covered ($m \cdot min^{-1}$) in the first half (0-45 min) to that of the opening 15-min of the second half, using both 5- (46-50, 51-55, 56-60 min) and 15-min (46-60 min) pre-defined match-periods. We hypothesised that using the 0-45 min as our criterion sampling period would attenuate the impact of the high-tempo start to the game, yet preclude the onset of fatiguing mechanisms, since 45 min of actual or simulated match-play has not impaired sprint performance,[4] or dynamic strength.[17] Furthermore, muscle glycogen stores are still relatively high at HT,[18] dehydration is mild (-0.7% body mass)[19] and whilst the core body temperature increases significantly during the first half of match-play (38.5-39.0°C),[4,19] this degree of thermal strain is not indicative of fatigue associated with hyperthermia (~40°C)[20]. Whilst equally arbitrary, we considered that the first 45 min of match-play would provide a more representative sample of typical player work-rate upon which to base subsequent inferences of reduced physical performance. The 'frantic' opening 15 min should however be encompassed in any within-match analysis comparator to avert under-estimation of the match demands.

Data are presented as the mean (SD) and all analyses were performed on the log transformed data. A priori, we defined the minimal practically important difference as 0.2 between-subject standard deviations. Inference was based on the disposition of the confidence interval for the mean difference to this smallest worthwhile effect; the probability (percent chances) that the true population difference between first and second half is substantial (> 0.2 SDs) or trivial was calculated. These percent chances were qualified via probabilistic terms assigned using the following scale: <0.5% most unlikely or almost certainly not, 0.5–5% very unlikely, 5–25% unlikely or probably not, 25–75% possibly, 75–95% likely or probably, 95–99.5% very likely, >99.5% most likely or almost certainly.[21] The magnitude-based inference approach detailed by Batterham and Hopkins [11] was preferred as this technique provides a content-rich descriptor, which identifies the probability that the true value has the observed magnitude. Effect sizes (ES), with uncertainty of the estimates shown as 90% confidence intervals, for the between-half differences in TD, LSR and HSR were also determined using a custom-made spreadsheet [22] and classified as trivial (<0.2), small (0.2 to 0.6), moderate (0.6 to 1.2), large (1.2 to 2.0), very large (2.0 to 4.0) and extremely large (>4.0).[21]

Results

The mean (SD) total match distances are presented in Table 1. Low- and high-speed running constituted 82 (3%) and 18 (3%) of the total match distance, respectively. The relative distance covered for TD, LSR, and HSR during the pre-determine match-periods are presented in Figure 1.

The difference in relative distance (m•min^{-1}) between the opening 15-min period of the second half (46-60 min) when compared to the first half mean was -7.4 m (90% confidence interval -9.8 to -5.0 m) for TD, -5.3 m (-8.3 to -2.3 m) for LSR, and -2.1 m (-3.9 to -0.4 m) for HSR. These differences were *almost certainly* substantial for TD (ES -0.58; 90% confidence interval -0.77 to -0.40), *very likely* substantial for LSR (ES -0.56; -0.83 to -0.30), and *likely* substantial for HSR (ES -0.42; -0.72 to -0.13).

The difference in relative distance between the opening 5-min period of the second half (46-50 min) when compared to the first half mean was -21.3 m (-26.7 to -15.9 m) for TD, -15.5 m (-20.6 to -10.4 m) for LSR, and -5.8 m (-7.6 to -4.0 m) for HSR. These differences were *almost certainly* substantial for TD (ES -1.85; -2.37 to -1.33), LSR (ES -1.74; -2.32 to -1.17), and HSR (ES -1.37; -1.76 to -0.97).

The difference in relative distance between match period 51-55 min and the first half mean was -1.7 m (-4.9 to 1.4 m) for TD, -0.5 m (-3.7 to 2.7 m) for LSR, and -1.2 m (-4.1 to 1.6 m) for HSR. These differences were *possibly* trivial for TD (ES -0.13; -0.36 to 0.09) and LSR (ES -0.10; -0.39 to 0.19), and *possibly* substantial for HSR (ES -0.39; -0.97 to 0.19).

The difference in relative distance between match period 56-60 min and the first half mean was -0.2 m (-2.6 to 2.1 m) for TD, -0.7 m (-3.2 to 1.8 m) for LSR, and 0.5 m (-1.1 to 2.0 m) for HSR. These differences were *likely* trivial for TD (ES -0.04; -0.21 to 0.12) and LSR (ES -0.11; -0.31 to 0.09), and *possibly* trivial for HSR (ES 0.11; -0.14 to 0.36).

Discussion

The purpose of the current study was to re-examine the work-rate of soccer players immediately after a passive HT interval. When using first half relative mean distances ($m \cdot min^{-1}$) as the comparator, there were substantial reductions in the players' TD, LSR and HSR during the opening 15-min of the second half, albeit with small effect sizes. When using 5-min periods for the comparison, there were also substantial reductions in relative TD, LSR and HSR in the early stages of the second half (46-50 min), yet in the subsequent 5-min periods (51-55 min, 56-60 min), these reductions were trivial.

The findings of this study are in support of others that have shown reduced player physical performances after HT.[1,2,3] However, these studies utilised the opening 15-min of the first half of the match as the criterion for the comparison. This period has been characterised as the most frantic and intense match period[8,10] perhaps due to an assertive tactical strategy, pre-match motivational instructions, and player arousal. Accordingly, any subsequent physical performance decrements may be more indicative of a settled-down match-tempo,[8] a subconscious pacing strategy,[23] or the match status.[24] Our study extends previous work [4,5,25] by using the relative work-rate from the first half as our criterion for comparisons. Even when using this alternative criterion measure - one that we considered more representative of the overall first half physical demand - a decrement in all match running measures was still evident in the opening 15-min period of the second half.

Ultimately, a research design that uses 15-min segmentation of physical performance data is not sensitive to the intricacies of the work-rate pattern.[9] As such, we used 5-min match periods to provide a more thorough examination of the post-HT reduction in soccer players' physical performance. Such an approach provides support to previous investigations that have evidenced a post-HT reduction in player work-rate[1,2,3] as our findings demonstrated large reductions in all measures of match running performance in the 5-min period (46-50 min) that immediately followed the HT interval. However, this reduction was transient in nature as it was not evident in the following 5-min match periods (51-55 min, 56-60 min) where there were only small, trivial reductions in physical performance during these periods when compared to the first half mean. Therefore, in accordance with Mohr et al.[2] our findings provide evidence that the 15-min segmentation of match running data is a technique that is insensitive to intricacies of the activity profiles of elite-level soccer players.

Studies have shown reduced soccer-specific sprinting,[4,5] jumping,[5] dynamic strength,[5] and endurance performance[25] capacities after a passive HT; in each of these investigations the performance decrements were attenuated with a moderate intensity re-warm-up in the latter stages of the HT break. This has been attributed to maintenance of optimal muscle temperature.[4,5,25] From this perspective, our findings may be attributed to the 0.15 - 0.38°C•min^{-1} rate of increase observed within minutes of moderate intensity exercise.[26,27] Hence, the muscles' optimal capacity to perform high-intensity actions after a passive HT may be restored within 4-10 min of the re-start, which might explain the transient reduction in player work-rate. However, given the multi-factorial influences on soccer work-rate, it is unclear whether muscle temperature *per se* would explain the post-HT decrement observed in this study, and further research examining the effects of HT re-warm-up strategies on player physical performance is required in match-play settings, using randomised controlled trials.

Caution must be taken when generalising the observations of the current study where elite youth players were examined. The reduced TD and HSR denoted here in the first few minutes after the re-start, contrasts directly to the data presented by Weston et al.[10] in a large sample of English Premier League players. The reasons for this discrepancy are unclear, however may be explained by differences in the experience, fitness characteristics, or half-time strategy of the players. Since elite players cover more distances during match-play at high-speeds[2,28] without superior fitness characteristics, have a reduced inter-half disparity in work-rate,[2,28] and have greater *a priori* knowledge of the match demands, a sub-conscious pacing strategy based on prior experience[23] may explain the disparity between the current data and that of Weston and co-workers.[10] Alternatively, these differences might be explained by the half-time strategy adopted by the players. In this study the elite-youth players had a passive rest period whilst receiving extensive technical feedback at HT as part of their development and education. It is unknown what strategies the professionals in the Weston et al.[10] study undertook at HT, as a number of studies have recently shown the ergogenic benefits of brief re-warm-up activities[4,5,25] practitioners may be administering these interventions.

Whilst this study has attempted to provide a more in-depth analysis of the post-HT work-rate, its impact upon match outcome is unknown and there are other confounding factors that should be acknowledged. We did not record ball possession statistics and the amount of time that the ball was ‘in-play’, which may have impacted on the work-rates reported here. Furthermore, the use of velocity bands to determine physical match performances likely underestimates the energetic demands such as collisions, accelerations, decelerations, unorthodox running and turns, which often occur at velocities below 15 $km \cdot h^{-1}$. Hence, future work might seek to measure internal loads (i.e. heart rate) and also tri-axial accelerometry, to determine within-game work-rate patterns. Finally, whilst the players in the current study represented the range of soccer positional roles, we did not have sufficient sample size to determine if the post-HT work-rate decrement was dependent upon this factor. It might be expected that players who dictate their own work-rate by performing more 'off the ball' HSR, such as wide defenders and midfielders,[29] would show a greater reduction in HSR post-HT, but further research is warranted to investigate this.

Conclusion

In summary, this study demonstrated that elite youth players' physical performances were substantially lower in the first 5-min after a passive HT. However, this phenomenon was transient in nature. The analytical contrasts adopted in this re-examination provide a more rigorous assessment of reductions in match physical performance and researchers might consider using analogous procedures to examine reduction in physical performances across competitive matches. Further research is also required to determine if the post-HT decrement in performance is population-specific, and to decipher if it is caused by insufficient physical preparation as a consequence of a passive HT, or whether players adopt a sub-conscious pacing strategy to attenuate fatiguing symptoms in the latter stages of match-play.

Practical applications

- Elite-youth soccer players' work-rate is substantially reduced in the first 5-min of the second half after a passive half-time interval;
- Analysts and researchers of time-motion data might re-consider their analytical approach to determine player work-rate patterns during match-play;
- Pre-determined 5-min sampling periods are more sensitive to detect trends in post-HT work-rate data.

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Table 1 Mean (SD) match distance data, expressed in absolute (m) and relative (m•min^{-1}) terms

	Unit	First Half	Second Half	Match
Total Distance	Total (m)	5004 (699)	4638 (617)	9642 (1279)
	m•min^{-1}	111.2 (15.5)	103.1 (13.7)	107.1 (14.2)
Low-Speed Running	Total (m)	4080 (542)	3822 (513)	7902 (1030)
	m•min^{-1}	90.7 (12.0)	84.9 (11.4)	87.8 (11.4)
High-Speed Running	Total (m)	924 (246)	817 (209)	1740 (423)
	m•min^{-1}	20.5 (5.5)	18.2 (4.7)	19.3 (4.7)

Figure Legend

Figure 1 Mean relative (m•min^{-1}) total distance (A), low-speed running (B) and high-speed running (C) for the first half and the second half periods of 46-60 min, 46-50 min, 51-55 min and 56-60 min.