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Variations in high-intensity running and fatigue during semi-professional soccer matches

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Abstract

The aim of the study was to determine the fatigue rates and pacing strategies of players during matches by quantifying high-intensity running (HIR) in rolling 5-min periods. Ten semi-professional players were monitored with 10Hz global positioning system (GPS) units during 12 official A-league matches. Match data was categorised into total distance covered and HIR (>3.7 m/min) for rolling 5-min intervals. Distance covered in the first half were used to classify players into low- (LAG), moderate- (MAG) and high-activity groups (HAG). The MAG showed a moderate difference in HIR at 5-min after the peak period. The HAG showed moderate to large declines in distance covered between the first 15 min of the second half (103.9 m/min). They also showed small to moderate declines in HIR during the first 10 min of the second half (25.7 m/min). The LAG showed a small to moderate increase in distance covered during the last 10 min of the second half (95.7 m/min) compared to the first half (84.4 m/min). First-half activity profiles had a significant impact on recovery after the most intense 5-min periods. Also, our study showed an end-spurt occurring towards the end of a match supporting the possibility of pacing strategies.

Key words: football; fatigue; match analysis; GPS; pacing

1. Introduction

Soccer is an intermittent sport characterised by repeated bouts of high-intensity running (HIR) interspersed with periods of rest or low-intensity running (LIR) (Little & Williams, 2007). By monitoring variations in HIR researchers can make certain inferences about the fatigue that occurs during match-play (Aughey, 2010; Mugglestone *et al*., 2012; Varley *et al*., 2012a). Transient fatigue usually occurs after an intense period in the match leading to less HIR in subsequent periods of play (Edwards & Noakes 2009). Numerous studies have found a decrease in distance covered and HIR during the second half of matches and attributed these reductions to fatigue (Bradley *et al*., 2009; Bradley *et al*., 2010; Mohr *et al*., 2010). Furthermore, research suggests that player's training status may influence fatigue during match-play (Mohr *et al*., 2010).

However, variations in HIR may also be attributed to pacing rather than fatigue (Drust *et al*., 2007; Edwards & Noakes, 2009). Waldron and Highton (2014) stated that soccer seems to show a "slow positive" pacing strategy with players starting with a positive approach and then gradually showing a decline in distance covered and HIR. Aughey (2010) also suggested that players who pace themselves throughout a match would have the ability to show an "end-spurt" in HIR towards the latter part of a match. To our knowledge the occurrence of an "end-spurt" during soccer matches as well as the possible influence of training status on the fatigue pattern and rate of soccer players during match-play have not been investigated.

Although several studies found a reduction in HIR towards the final 15-min period of a soccer match (Bradley *et al*., 2009; Bradley *et al*., 2010; Mohr *et al*., 2010) others questioned the use of 15-min periods throughout a match to monitor fatigue (Mohr *et al*., 2003; Lovell *et al*., 2013). Therefore several studies have used pre-determined 5-min intervals and found that after the most intense period of activity, a decline below the match average in HIR occurs during the subsequent 5-min period (Bradley *et al*., 2009; Bradley *et al*., 2010; Mohr *et al*., 2010; Bradley & Noakes, 2013). The decline in HIR during these periods indicate transient fatigue, but using pre-determined intervals could lead to under- or overestimations in the reduction of these activities (Bradley *et al*., 2010). Thus Varley *et al*. (2012a) suggested using a rolling time scale which determines the distance covered after every time point for the next 5-min period. Even though the last-mentioned technique may increase the accuracy of fatigue measurements, another factor that needs to be considered when determining fatigue status is the possible influence of players' training status on match-play fatigue (Mohr *et al*., 2010). In this regard a significant correlation was found between Yo-Yo Intermittent Recovery level 1 test (Yo-Yo IR1) results and the amount of HIR performed during the final 15 min of soccer match halves in elite female players ($r = 0.83$) (Krustrup *et al*., 2005). A significant relationship has also been observed between Yo-Yo IR1 results and the amount of HIR performed during the final 15 minutes of a soccer match ($r = 0.51$) (Mohr *et al*., 2010). With this in mind, the Yo-Yo IR1 is not only an indicator of a players' training status but can also be used to determine the effect of training status on the fatigue patterns of players during matches.

In summary the above findings would suggest that a rolling time scale can be used to accurately determine fatigue rate and patterns in soccer players during match play and that training status and pacing may influence the activity profiles of players. Therefore the aims of this study were to: (1) determine the fatigue patterns by quantifying the HIR performances in rolling 5-min periods during semi-professional soccer matches and (2) determine the influence of players' training status on fluctuations in HIR during match-play.

2. Methods

2.1. Subjects

Ten male, semi-professional players (age 22.1 ± 2.5 y; stature 172.5 ± 7.5 cm; mass 63.5 ± 9.6 kg) from a South African university's first team participated in the study. Players gave informed consent and the study was approved by the Health Research

Ethics Committee of the university (NWU-00200-14-A1). Only field players (no goalkeepers) were included in this study. Players were assessed during the competitive phase of their periodization cycle. For the players' data to be included in the study they had to complete the entire match and they needed to partake in a Yo-Yo IR1 at least two weeks before or after each match. The players also needed to be healthy and injury free at the time of testing.

2.2. Design

An observational study design was implemented and data was collected from 12 official A-league matches (highest semi-professional league in South-Africa) and pre-match testing. Players completed a Yo-Yo IR1 at least two weeks before or after each match on a Wednesday to allow enough recovery between matches that took place over the weekends. All matches were played on standard-size outdoor fields with 11 players a side. Games had 45-minute halves and were played in accordance with the rules of the South African Football Association (SAFA) and refereed by qualified officials.

2.3. Methodology

The Yo-Yo IR1 is regarded to be a valid exercise test to evaluate the ability of players to perform HIR and a significant correlation has been shown between maximal oxygen uptake ($\dot{V}O_{2max}$) and Yo-Yo IR1 results ($r = 0.70$, $p < 0.05$) (Bangsbo *et al*., 2008). The Yo-Yo IR1 procedure has been described in detail elsewhere (Bangsbo *et al*., 2008) and all players were familiar with the Yo-Yo IR1 as they had performed it previously. The test was conducted on a grass soccer field and players wore their soccer boots. Players also wore Fix Polar Heart Rate Transmitter Belts (Polar Electro, Kempele, Finland), which recorded heart rate at 5-second intervals.

Matches were analysed with GPS units sampling at a frequency of 10 Hz (MinimaxX V4.0, Catapult Innovations, Victoria, Australia). The average number of satellite signals was 10.1 ± 0.1 and horizontal dilution of precision, 0.96 ± 0.05. Recordings from GPS unit were downloaded to a PC and analysed with the Logan Plus V4.7.1 software (Catapult Sports, Victoria, Australia). GPS Doppler data was used during analyses of the GPS-related variables. Johnston *et al*. (2014) found the inter-unit reliability of the 10 Hz devices to be good (typical error of measurement 1.64%) when peak speed was measured. The units were also found to be reliable for measuring instantaneous velocity (coefficient of variation 1.9–6.0%) (Varley *et al*., 2012b). For a movement to be recorded as an effort, players had to maintain that velocity for at least 1s. The absolute (m) and relative (m/min) total distances covered by players as well as the absolute (m) and relative (m/min) distances covered at a velocity of >3.7 m/s were recorded during matches. This threshold for HIR is consistent with previous studies (Di Salvo *et al*., 2007; Rampinini *et al*., 2007; Castellano & Casamichana, 2010). The most intense period was classified as the peak distance covered in HIR for a 5-min interval from every time point sampled. In order to monitor recovery after this period, comparisons were drawn between the average 5-min period (excluding peak) and the subsequent 5-min periods up to a maximum of 15 min (Varley *et al.*, 2012a; Bradley & Noakes, 2013). Furthermore, in order to compare performances during pre-defined 5-min periods in the second half players were classified in the following groups according to distances covered during the first half: low- (LAG), moderate- (MAG) and high-activity group

(HAG). Data was sorted using percentiles to produce each level (low: ≤30th; moderate: 35–65th and high: ≥70th percentile) according to the method of Bradley and Noakes (2013). Players also wore a Fix Polar Heart Rate Transmitter Belt (Polar Electro, Kempele, Finland), which recorded heart rate at 5-second intervals for the duration of each match.

2.4. Statistical Analysis

Descriptive statistics (mean, SD) were calculated and all variables were normally distributed. A bivariate correlation was performed to determine whether Yo-Yo IR1 results correlated with match related variables. A factorial analysis of variance (ANOVA) and a Bonferroni post-hoc test were performed to determine differences between activity groups for all variables. Furthermore, a dependant t test was performed to determine differences between the most intense periods of the match and subsequent periods as well as to determine any differences between the pre-determined periods of the match. The p-value was set at ≤ 0.05.

3. Results

The maximum heart rate during the Yo-Yo IR1 for all players was 192 bpm and the average heart rate during matches was 159 bpm. Yo-Yo IR1 results were not correlated with any of the HIR and recovery related variables. Results of the Yo-Yo IR1 and match variables are presented in Table 1 for each of the activity groups. The peak 5-min period of the HAG was significantly ($p \leq 0.05$) higher than the peak period of the LAG ($p < 0.001$) and MAG ($p = 0.004$). In the HAG, the subsequent 5-min period after the peak period was significantly ($p \leq 0.05$) higher compared to the LAG ($p < 0.001$) and MAG ($p = 0.011$). Furthermore, the HAG showed higher ($p \leq 0.05$) values at 10- and 15-min after the peak period compared to the LAG ($p = 0.002$ and $p < 0.001$). However, when the post-peak period values were expressed relative to the peak period no significant differences were found. Figure 1 shows the distance covered (m/min) by HIR for each activity group. When the 5-min periods following the peak 5-min period are compared with the average distance covered in HIR, the HAG shows non-significant differences ($p \geq 0.05$). However, the LAG showed a significant difference in HIR ($p = 0.002$) at 5 min and a significant difference ($p = 0.052$) at 15 min after the peak period compared to the average 5-min period. Similarly, the MAG showed a significant difference in HIR ($p < 0.001$) at 5 min after the peak period, but no significant ($p \geq 0.05$) difference was observed after that period.

Table 1. Yo-Yo IR1 and match variables (mean ± SD) for low- (28 files), moderate- (27 files) and high-activity (28 files) groups.

Variables	Low activity	Moderate activity	High activity	Total
Yo-Yo IR1 (m)	1338 ± 388	1333 ± 445	1422 ± 501	1365 ± 443
1st half TD (m)	4201 ± 388[ab]	4938 ± 136[ac]	5520 ± 256[bc]	4886 ± 612
Peak 5-min (m/min)	37.4 ± 8.7[a]	47.4 ± 10.0[b]	62.5 ± 25.7[ab]	49.1 ± 19.6
Post 5-min (m/min)	13.9 ± 8.5[a]	17.5 ± 9.7[b]	25.9 ± 12.0[ab]	19.1 ± 11.2
Post 5-min (% of peak)	36.9 ± 22.1	36.6 ± 19.3	44.4 ± 20.6	39.3 ± 20.7
Post 10-min (m/min)	17.6 ± 11.3[a]	22.8 ± 10.4	30.1 ± 13.4[a]	23.3 ± 12.7
Post 10-min (% of peak)	45.1 ± 23.2	46.3 ± 18.2	52.0 ± 21.9	47.7 ± 21.2
Post 15-min (m/min)	14.3 ± 10.4[a]	21.1 ± 9.2	29.6 ± 14.8[a]	22.0 ± 13.3
Post 15-min (% of peak)	38.4 ± 25.8	44.1 ± 19.0	51.4 ± 24.3	45.0 ± 23.5

[abc] significant ($p < 0.05$) differences between corresponding letters. Yo-Yo IR1 – Yo-Yo Intermittent Recovery test 1; TD – Total distance

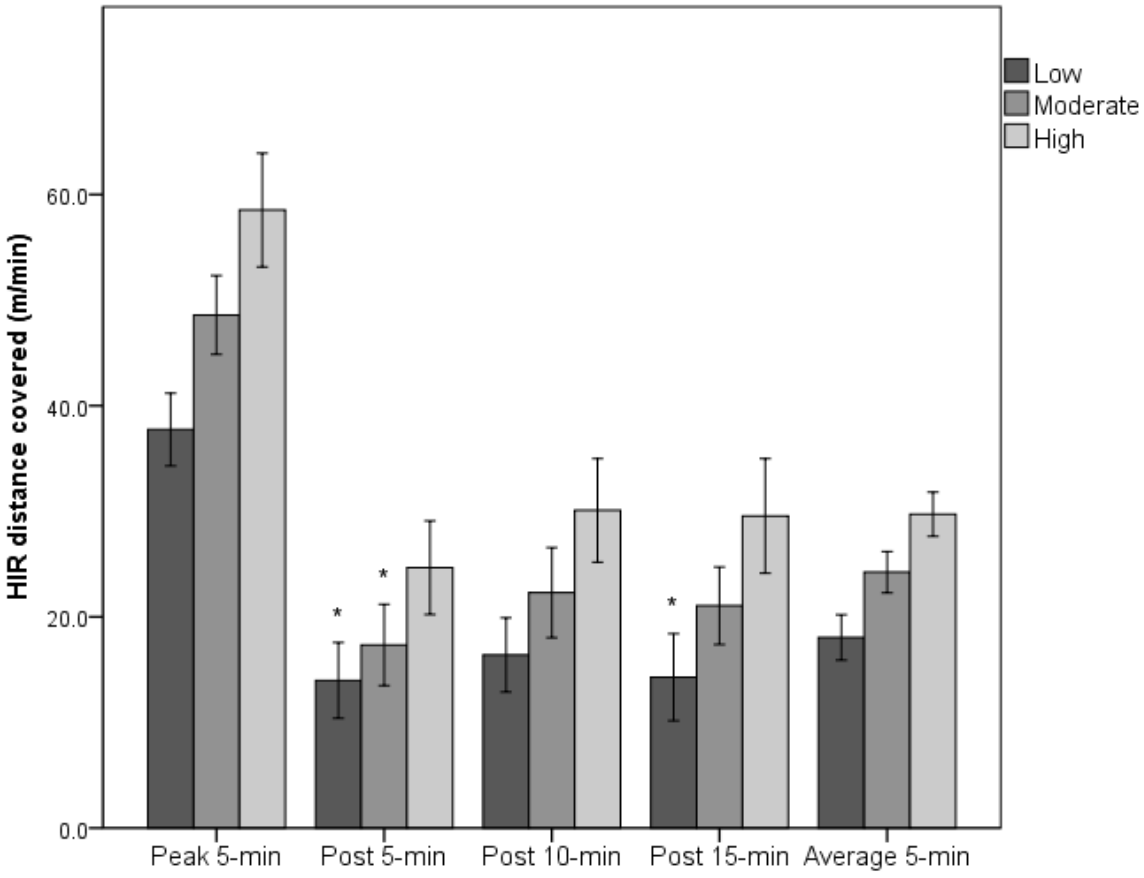

Figure 1. Distance covered (m/min) in high-intensity running (HIR) for the most intense 5-min period and the subsequent 5-min periods. *Lower ($p \leq 0.05$) than the average 5-min period minus the peak value. Data presented as means and 90% confidence interval.

Figure 2 illustrates the differences between pre-determined 5-min periods for total distance (m/min) covered and Figure 3 illustrates the differences between pre-determined 5-min periods for distance covered (m/min) by HIR. The MAG showed no significant ($p \leq 0.05$) differences when comparing the pre-determined 5-min periods between the first and second halves for both total distance covered and distance covered by HIR. However, the HAG showed a significant ($p \leq 0.05$) decline in distance covered between the first 15 min of the second half (103.9 ± 25.5 m/min) compared to the first 15 min of the first half (122.5 ± 18.8 m/min). The HAG also showed a significant ($p \leq 0.05$) decline in HIR during the first 10 min of the second half (25.7 ± 12.0 m/min) compared to the corresponding period in the first half (34.1 ± 14.1 m/min). Furthermore, the HAG showed a significant ($p \leq 0.05$) decline in distance covered during the 70–75th minute compared to the 25–30th minute (105.3 ± 23.1 m/min vs 120.1 ± 18.0 m/min) and a significant ($p \leq 0.05$) decline during the last 5-min period of the second half compared to the first half (102.3 ± 25.7 m/min vs 116.2 ± 29.2 m/min). The LAG showed a significant ($p \leq 0.05$) decline in distance covered during the first 5 min of the second half (76.3 ± 23.6 m/min) compared to the first half (87.7 ± 17.7 m/min). Conversely the LAG showed a significant ($p \leq 0.05$) increase in distance covered during the last 10 min of the second half (95.7 ± 17.9 m/min) compared to the first half (84.4 ± 17.4 m/min) as well as a significant ($p \leq 0.05$) increase in HIR during the 80–85th minute compared to the 35–40th minute (19.9 ± 11.2 m/min vs 13.3 ± 8.7 m/min).

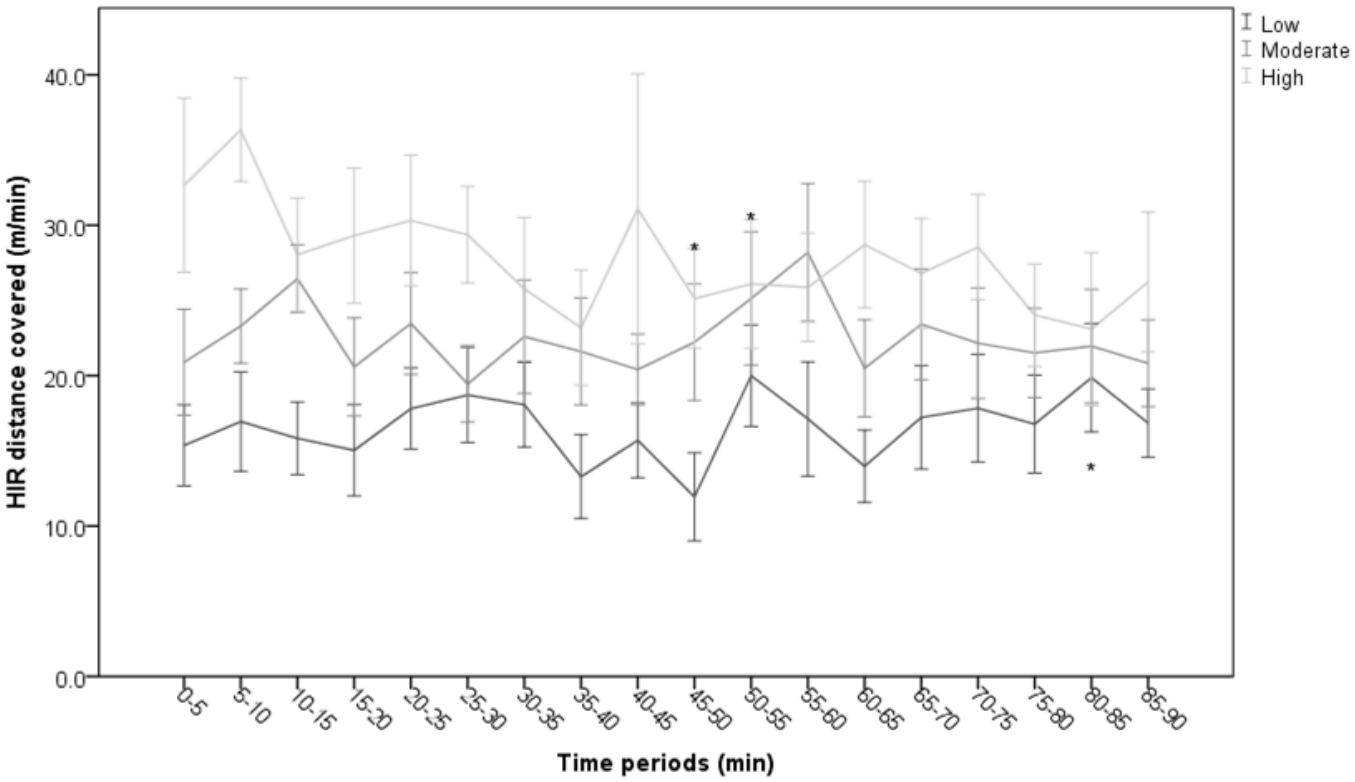

Figure 2. Total distance (m/min) covered by players during pre-determined 5-min periods. *Significantly ($p \leq 0.05$) different from corresponding 5-min period in the first

half.

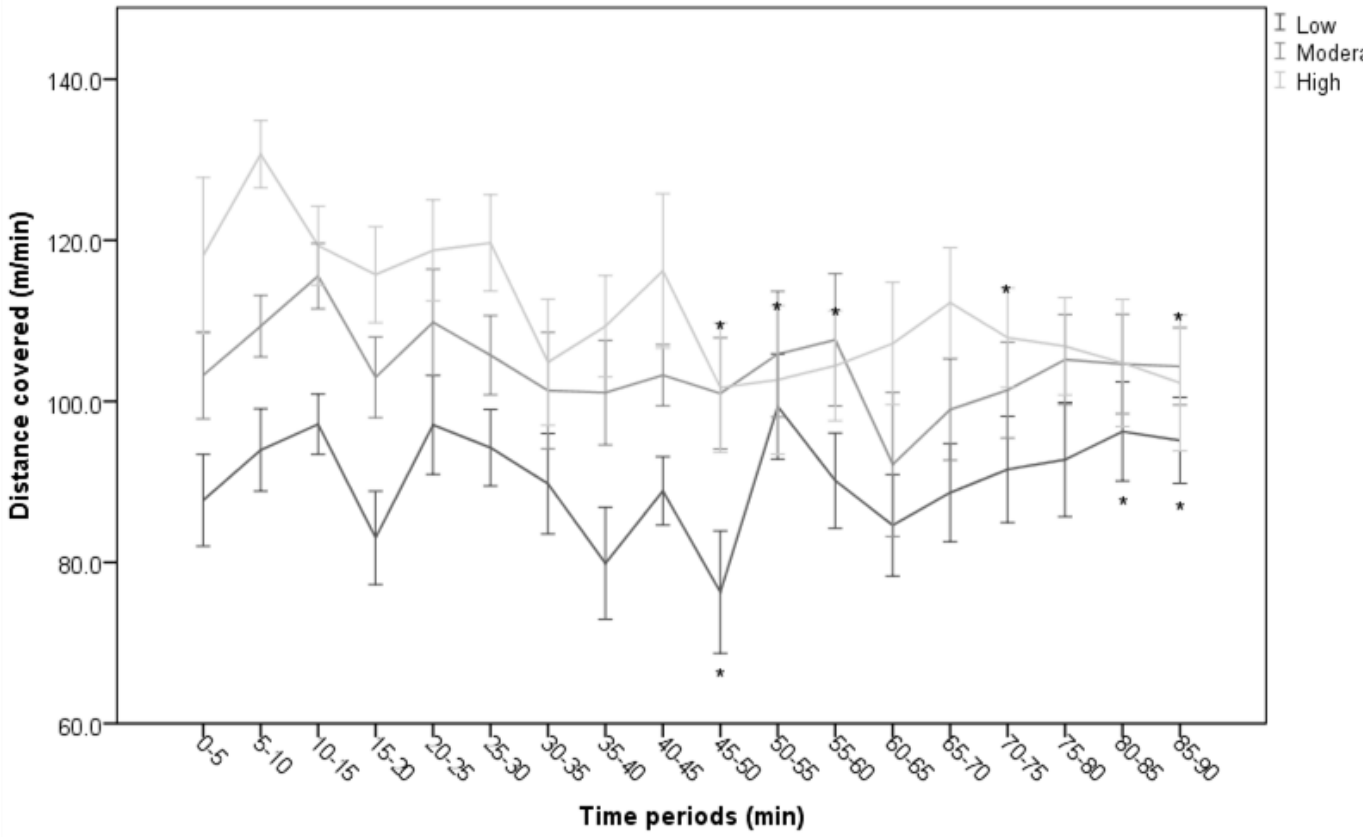

Figure 3. Total high-intensity running (HIR) distance (m/min) covered by players during pre-determined 5-min periods. *Significantly ($p \leq 0.05$) different from corresponding 5-min period in the first half.

4. Discussion

The aims of this study were to determine the fatigue patterns by quantifying the HIR performances in rolling 5-min periods during semi-professional soccer matches and to determine the influence of players' training status on fluctuations in HIR during match-play. One of the main findings is that first-half match performance had a significant influence on HIR after the most intense 5-min period as well as on second-half match performance. Furthermore, we found that training status had no influence on any of the HIR or fatigue-related variables.

To the authors' knowledge this is the first study to have used 10 Hz GPS and rolling 5-min periods to determine how the most intense periods influence the subsequent 15 min periods of competitive soccer matches. A comparison between the 5-min periods after the most intense 5-min period and the average 5-min period for each group revealed that none of the HAG's recovery periods differed significantly from that of the average 5-min period. On the other hand, the LAG showed significantly lower HIR values for both the post-5-min and post-15-min periods, whereas the MAG showed significantly lower values at the post-5-min period. Although several researchers observed a significant

decline in the post-5-min period after the most intense period (Bradley *et al*., 2009; Bradley *et al*., 2010; Mohr *et al*., 2010; Bradley & Noakes, 2013), none of them differentiated between activity levels in the first half. Incidentally, Bradley and Noakes (2013) investigated the post-10- and post-15-min periods and found no significant decreases in HIR compared to the average 5-min period. It is noteworthy that these studies were performed on professional soccer players whereas our study focused on semi-professional soccer players. Despite these differences in participation levels the peak 5-min period (49.1 m/min) for all groups in this study is similar to the values reported by Bradley *et al*. (2009) (46.2 m/min) and Bradley *et al*. (2010) (48.2 m/min). However, the first 5-min period after the peak period (19.1 m/min) was slightly lower for this study compared to values of previous studies (25.2 m/min and 22.8 m/min, respectively).

Comparisons between the first and second halves show that the MAG was able to maintain the same distance and HIR distance throughout the entire match without any significant differences between 5-min periods. However, the LAG showed a decline in distance covered during the first 5 min of the second half. Interestingly the LAG covered a higher average distance during the final 10 min and a greater HIR distance during the 80th min period of the match. In contrast, the HAG showed a decline in distance covered during the first 15 min of the second half as well as a decrease in HIR during the first 10 min of the second half. Additionally the HAG also displayed a decrease in distance covered during the 70–75th and 85–90th min periods. Bradley and Noakes (2013) also reported significant decreases in distance covered and HIR during the first 10 min of the second half as well as declines in distances covered during the 70th and 85th minute for the HAG. These researchers also observed declines in distances covered during the first 10 min of the second half for the LAG and MAG whereas only the LAG showed significant declines in our study. Although Mugglestone *et al*. (2012) did not differentiate between players' activity levels during the first half, they also observed declines in HIR during the first 5 min of the second half in semi-professional matches. Declines in match performances during the first 10 minutes of the second half could be attributed to the fall in muscle temperature during the half-time break as Mohr *et al*. (2004) found a significant positive correlation between muscle temperature after the half-time break and HIR performance during the second half.

Results of our study also support notions by others that players may pace themselves during matches with an end-spurt occurring towards the end of a match (Edwards & Noakes, 2009; Aughey, 2010; Bradley & Noakes, 2013). Waldron and Highton (2014) suggested that soccer players who played the whole match adopt a 'positive' pacing strategy, which means that the intensity of running slowly decreases as the match progresses. However, the LAG was able to increase the distance covered during the last 10 min of the match, demonstrating an end spurt at the end of the match. These findings suggest that the first half performance influences the type of pacing strategy used by players who participate in the whole match. However, caution is needed when only attributing these results to fatigue or pacing strategies, since several contextual factors such as different players' tactical roles and actual ball in play time may also influence results (Carling *et al*., 2008; Paul *et al*., 2015). Furthermore, the HIR threshold was set at distances covered at a velocity of >3.7 m/s, which meant that accelerations and

decelerations were not considered when determining HIR values. Therefore, HIR could have been underestimated in this study.

In contrast to previous studies that reported strong correlations between Yo-Yo IR1 performance and HIR match performances (Krustrup *et al*., 2003; Bangsbo *et al*., 2008), this study found no significant correlations between Yo-Yo IR1 performance and any of the locomotor variables. In addition, even though Mohr *et al*. (2010) reported a significant correlation (r = 0.51) between Yo-Yo IR1 performance and the distance covered in HIR during the last 15 min of a match, the present study revealed no such correlation. In the present study, similar Yo-Yo IR1 values were observed among participants resulting in a low standard deviation. It is therefore possible that the homogeneity of the Yo-Yo IR1 results led to the poor association with match-play HIR (Hopkins, 2000). Nonetheless, it is noteworthy that although there were no significant correlations between Yo-Yo IR 1 and activity profiles, the Yo-Yo IR1 results were higher for players in the HAG. This suggests that while Yo-Yo IR1 and the locomotor variables were not directly associated, a higher Yo-Yo IR1 performance contributed to a better first-half performance in the HAG. However the Yo-Yo IR1 determined maximum heart rate (192 bpm) and the average match heart rate (159 bpm) would suggest that players only performed at 83% of their maximum heart rate. The intensity of match play was therefore not high which indicates that players' fatigue did not play as big a role as the pacing strategy adopted during match play.

5. Conclusions

In conclusion, this is the first study to have used 10 Hz GPS and rolling 5-min periods to determine the most intense periods in competitive soccer matches and the possible influence of these periods on subsequent activities during the following 5-min periods. We found no relationship between Yo-Yo IR1 performance and HIR running or recovery variables, but results suggest that high Yo-Yo IR1 performances contribute to better first-half performances. Also, first-half activity profiles had a significant impact on recovery after the most intense 5-min periods as well as on second-half performances, which may be attributed to the presence of transient fatigue. Our study also supports the possibility that players pace themselves during matches with an end-spurt occurring towards the end of a match. However, future studies should take into account the contextual factors which may influence the match performance of players.

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