RUNNING DEMANDS AND HEART RATE RESPONSE IN RUGBY UNION REFEREES

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ABSTRACT

Suarez-Arrones, L, Portillo, LJ, Garcı´a, JM, Calvo-Lluch, A, Roberts, SP, and Mendez-Villanueva, A. Running demands and heart rate response in rugby union referees. J Strength Cond Res XX(X): 000–000, 2013—The aim of this study was to examine the match physical demands and exercise intensity associated with men rugby union refereeing using global positioning system technology. Ten male rugby union referees (age, 37.1 ± 5.9 years; body mass, 83.7 ± 4.8 kg; height, 175.5 ± 6.2 cm) were analysed 2–4 times during a total of 30 national level matches. The average total distance covered by the referees throughout the game was 6,322.2 ± 564.9 m. As a percentage of total distance, 37.3% (2,356.9 ± 291.3 m) was spent walking, 24.1% (1,524.4 ± 229.4 m) jogging, 10.4% (656.2 ± 130.7 m) running at low intensity, 17.6% (1,110.3 ± 212.2 m) at medium intensity, 5.5% (3,471 ± 27.1 m) at high intensity, and 5.2% (328.1 ± 230.3 m) at sprint. A significant decrease ($p < 0.05$) in running performance was observed between the first and the second halves in the last 3 speed zones. When the total distance travelled during consecutive 10-minute periods was compared, there was a significantly greater distance covered in the first 10 minutes of the game (876.3 ± 163 m) compared with 50–60 minutes (679.8 ± 117.6 m), 60–70 minutes (713.03 ± 122.3 m), and 70–80 minutes (694.2 ± 125.7 m; all $p < 0.05$). The average heart rate responses were similar ($p < 0.05$) in the first (157 ± 7 b.min^{-1}; 85% HRmax) and second half (155 6 7 b.min^{-1}; 84% HRmax). This study provides evidence of reduced high-intensity running toward the end of the game. These findings offer important information to design better training strategies adapted to the requirements and demands of rugby union refereeing.

INTRODUCTION

Every rugby union match is under the control of match officials who consist of the referee and 2 touch judges or assistant referees. The referee is the sole judge of fact and is required to apply the Laws of the Game in every match (9). As such, decisions taken by the referee during play can determine the final result of the match. Several studies have shown that physical performance, accuracy, and velocity of decision making of players and referees could be altered by the development of exercise-induced fatigue (12,15,16,19). The ability of the referee in rugby union to keep up with play to be in a good position is critical in allowing correct decisions to be made. Thus, the ability of the rugby union referee to meet the physical and physiological demands imposed during match play is believed to be a necessary prerequisite for optimal positioning and successful refereeing. To the author's knowledge, only 1 study has examined the physical demands on referees during rugby union official matches (14). However, the results of this study have limited practical applications because it used a subjective analysis method to categorize running activity and did not report heart rate (HR) responses. Understanding refereeing physical and physiological demands during competitive matches will assist in designing specific conditioning programs and physical fitness testing protocols in rugby union referees. Accordingly, the aim of this study was to examine the match physical demands and exercise intensity associated with men's rugby union refereeing with global positioning system (GPS) technology

METHODS

Experimental Approach to the Problem

In this investigation, an observational design was used to examine the match physical demands and exercise intensity during competitive rugby union matches. Ten male referees from the same national league (the highest level of rugby union in Spain) were investigated during 30 competitive matches in 1 season (2010–2011). Portable global position system (GPS) technology and HR responses were used to assess match physical demands and exercise intensity, respectively. Identification of referee movement patterns and the associated physiological responses during match play is important for optimizing training prescription and managing referee preparation for competition.

Subjects

Time-motion analysis data of physical activity were collected from 10 elite male rugby referees (age, 37.1 ± 5.9 years; body mass, 83.7 ± 4.8 kg; height, 175.5 ± 6.2 cm). All referees had a minimum of 4 years of experience at the highest level in Spanish or

Portuguese league and also in several international competitions. Typically, referees trained 4 $d.wk^{-1}$ and were involved (refereeing) in 4 games a month. Each referee provided written informed consent before his participation in this study. The experimental protocol was approved by the Institutional Ethics Committee (Pablo de Olavide University).

Experimental Procedures

Match analyses were performed 2–4 times on each referee during a total of 30 national matches played over a period of 9 months during the national league season. All the matches were played on standard outdoor natural grass fields. Playing time was 2 halves of 40 minutes each.

Activity Pattern Measurements

A GPS unit capturing data at 1Hz (SPI Elite, GPSports, Canberra, Australia) was fitted to the upper back of each referee using an adjustable neoprene harness. The devices were switched on 5 minutes before the game and immediately switched off at the end. The data stored include HR, time, speed, and distance. This GPS system uses signals from at least 3 earth-orbiting satellites to determine the referee's position at a given time and therefore allow the calculation of movement speeds and distance travelled (7,13). Despite a possible underestimation of high-intensity running distance with the time resolution of 1 Hz, good accuracy ($r = 0.97$) (2) and reliability (coefficient of variation = 1.7% [2] and 2.3% [4]) have been reported for the assessment of peak sprinting speed for this GPS device compared with an infrared timing system. Moreover, in the absence of a "gold standard" method (1), the current system has been reported to be capable of measuring individual movement patterns in other team sports (17,20,21).

Match Running Demand Analysis

Only the time-motion data for referees who participated in the entire first and second halves were retained ($n = 30$ files from 10 referees). After collection, all match data were analysed with the software provided by the manufacturer (Team AMS; GPSports, V1.2) designed to provide objective measures of physical match performance. Referees' activities were coded into the following categories and speed thresholds: walking (0.1–6.0 $km.h^{-1}$), jogging (6.1–12.0 $km.h^{-1}$), running at low intensity (12.1–14.0 $km.h^{-1}$), at medium intensity (14.1–18.0 $km.h^{-1}$), at high intensity (18.1–20.0 $km.h^{-1}$), and at sprint (20.1 $km.h^{-1}$). The speed thresholds for each category were the same as those reported previously in rugby using GPS technology (5,20,21). The above categories were divided into 2 further locomotor categories to provide an estimation of referee work-to-rest ratios (20,21): (a) low-intensity activity (0.1–6.0 km.h^{-1}) and (b)moderate-and-high-intensity activity (.6.1 km.h^{-1}). The frequency of high-speed zone entries (sprints .20.1 km.h^{-1}) and the highest speed recorded during the game were also collected. For every 10-minute period, calculations were made of the relative total distance travelled and relative high-intensity distance travelled throughout the match.

Heart Rate

Match exercise intensity was quantified by monitoring the HR during each match. The HR was continuously measured (1 Hz) with short-range telemetry (SPI Elite, GPSports, Canberra, Australia) and was expressed in relation to the individual HRmax estimated through the formula by Tanaka et al. (22). In those referees whose HRs were higher in the course of the match than the estimated HRmax, the HRmax values obtained during the game were retained and used in the analysis. The HR data were classified based on the percentage of total playing time spent in each of the following 6 HR zones (20,21): zone 1 (60% HRmax), zone 2 (61 70% HRmax), zone 3 (71–80% HRmax), zone 4 (81– 90% HRmax), zone 5 (91–95% HRmax), and zone 6 (96% HRmax).

Statistical Analyses

Data are presented as mean 6 SD. Differences between the first and second halves were determined using the Student dependent t-test. The differences between the distance covered at different movement intensities, distance covered at different periods, and time spent at different HR intensities were analysed using a 1-way analysis of variance with repeated measures. When a significant interaction was found, Bonferroni’s adjusted post hoc tests were applied. All analyses were carried out with SPSS 20.0 (SPSS Inc., Chicago, IL, USA) software with the level of significance set at $p \leq 0.05$. Standardized differences or effect sizes (ES) in match-play physical responses were also calculated, and the threshold values for Cohen ES statistics were trivial (0.0–0.19), small (0.2– 0.59), moderate (0.6–1.1), large (1.2–1.9), and very large (.2.0) (3,8).

RESULTS

Movement Analysis

The average total distance (±SD) covered by the referees throughout the game (84.9 6 2.9 minutes) was 6,322.2 ± 564.9 m with a range of 5,459–7,426 m. As a percentage of total distance, 37.3% (2,356.9 ± 291.3 m) was spent walking, 24.1% (1,524.4 ± 229.4 m) jogging, 10.4% (656.2 ± 130.7 m) running at low intensity, 17.6% (1,110.3 ±

212.2 m) at medium intensity, 5.5% (347.1 ± 27.1 m) at high intensity, and 5.2 % (328.1 ± 230.3 m) at sprint. A significant decrease ($p < 0.05$) in running performance was observed between the first and second halves in F1 the last 3 running categories (Figure 1). There was a significant difference in the total relative distance covered between the first and second halves (77.2 6 6.1 vs. 71.9 6 7.1 $m.min^{-1}$, respectively, $p < 0.05$). When the total distance travelled during consecutive 10-minute periods was compared, there was a significantly greater distance covered in the first 10 minutes (876.3 ± 163 m) compared with 50–60 minutes (-22.4 ± 3.9%), 60–70 minutes (-18.6 ± 3.2%, 713.03 ± 122.3 m), and 70–80 minutes (-20.9 ± 3.8%; all $p < 0.05$, respectively, Figure 2). Figure 3 shows the distance covered at high intensity and sprint (.18.1 $km.h^{-1}$) along the consecutive periods of 10 minutes. The greatest distance covered was also recorded during the first 10 minutes of the game (113.7 ± 59.4 m) with no significant differences and a small or moderate magnitude between periods. The referee's work-to-rest ratio was 1.7:1 (i.e., for every 1.7 minutes covered at a moderate-and-high-intensity speed [6.1 $km.h^{-1}$]), 1 minute was covered at low intensity ([0.1–6.0 $km.h^{-1}$]). The maximal speed obtained by the referee during a match was 28.2 $km.h^{-1}$, whereas the longest sprint recorded was 79.6 m. Referees registered maximum average speeds of 23.8 ± 1.8 $km.h^{-1}$. The number of sprints, maximal sprint distance, minimum sprint distance, and the average sprint distance during the game were 20.12 ± 12.2 sprints, 35.87 ± 14.7, 5.9 ± 1.5, and 15.5 ± 3.8 m, respectively. Sprint duration was 2.60 ± 0.67 seconds with 1 differences were found between the first and second halves for the number of sprints and the time that elapses between them (219.6 ± 11.78 and +20.3 ± 20.1%, all $p < 0.05$; Table 1).

Heart Rate

The average HR responses recorded in the first (157 ± 7 $b.min^{-1}$; 85 % of the estimated HRmax) and second half (155 ± 7 $b.min^{-1}$; 84 % HRmax of the estimated value) were similar ($p > 0.05$). The referees attained average values of HRmax of 183 ± 8 $b.min^{-1}$ (99 % of the estimated HRmax), with a similar HRmax recorded in the first half than in the second half (183 ± 8 vs. 182 ± 8 $b.min^{-1}$, $p > 0.05$). Figure 4 shows the percentage of playing time spent in each exercise intensity zone expressed as a percentage of the estimated HRmax during each half. Referees spent most of their playing time in zone 4 (i.e., between 81 and 90% HRmax), with significant differences observed between halves in several HR zones (Figure 4).

DISCUSSION

The purpose of this study was to carry out an analysis of the movement and the intensity of activity to which the referees are subjected during a rugby union match. An objective time-motion analysis method (GPS) was used also in conjunction with HR monitoring during the game. This is the first study to characterize the running movement patterns and exercise intensity of referees during rugby union matches using GPS technology. The results of this study showed that during a rugby union match the referees covered 6,323 m, which corresponds to a relative distance of approximately 75 m·min21. In the only other study to assess the distance travelled by rugby union referees, it was estimated that an average distance of 8,581 m (101 m·min21) was covered (14). It is possible that such differences may be attributed to the differing playing patterns in the Spanish top division compared with that in the English Premiership. However, direct comparisons between these 2 studies should be made with caution because of the different time motion analysis methods employed, with this study using an objective (GPS) methodology, whereas Martin et al. (14) estimated distance covered using a subjective method. With the same technology used in this study (i.e., GPS), it has been reported that elite male rugby union players covered a total match distance of 6,953m (5), which is in the range of the distance covered by the referees in this study.

One of the most important findings of this study was the diminution of the total distance covered (26.9 ± 0.7%) and the distance covered at .14.1 km.h^{-1} (211.2 ± 3.8%) during the second half of the match. This diminution in running performance as the game progresses was also demonstrated through a significant reduction (220.6 ± 3.6%) in the distance covered in the last 30-minute period of the match compared with the first 10 minutes. In addition, sprinting performance was substantially impaired in the second half, with fewer sprints performed and more time elapsed between consecutive sprints (Table 1). In contrast, there was no difference in the distance travelled by English Premiership referees over consecutive 10-minute match periods (14). It is not clear whether the reduction in the running performance during the second half observed in this study is because of the referee's fatigue or changes in the pattern of match play, because both are likely to influence the referee's movement patterns. In rugby union players, the greatest distance was also covered in the first 10 minutes of the match compared with 50–60 minutes and the 70- to 80-minute periods (18). However, these authors (18) did not find any difference in the distance covered at high intensity and sprint between any time period throughout the game. Similarly, others have found no substantial differences in the total distance covered at high intensities between the first and second halves in rugby union players (5,6). Although experience in tactical positioning to follow the game may partially compensate for the impaired running performance observed in the referees in comparison to what has been reported for players during the second half, there will be periods in a match when the referee will be required to cover ground very quickly to be close to an event and make accurate decisions. Present results might indicate a need for implementing specific fitness and conditioning strategies aimed to improve the ability to repeated high-intensity efforts in the last part of the game for referees being able to cope with a player's running activity. In this regard, the sprinting-related information provided in Table 1 can be used to program high-intensity, running protocols to mimic the demands of the game. The work-to-rest ratio, which reflects total high and moderate running speed exercise vs. total low running speed exercise time, reported in this study (i.e., 1.7:1) was much higher than the 0.6:1 estimated in the study of Martin et al. (14). Our results are similar to what could be estimated from the data reported in rugby league refereed (1.6:1) (10). Again, caution should be exercised when interpreting these differences because different time-motion analysis methods were employed. Nevertheless, the work-to-rest ratio obtained in this study can also help coaches to plan specific high-intensity intermittent exercise training protocols. The average HR of the referees in this study was approximately 85% of their estimated HRmax and approximately 28% of the total match time was spent above 90% of the estimated HRmax, with no differences between halves. This is the first study to report HR values in rugby union referees, and therefore, comparisons are not possible. One study has reported lower average HR values (80% of HRmax) in rugby league referees (11). Despite the only slightly lower running demands observed in rugby union referees (this study) in comparison with players (5), the latest spent substantially more time at intensities .90% of the estimated HRmax (46 vs. 28%, respectively). Albeit speculative, it is possible that the non locomotor high-intensity activities such as tackles, pushing and pulling in rucks, and scrums that the players have to carry out but not the referees, can be responsible for the somehow reduced HR responses observed in rugby union referees compared with that in players. In summary, this is the first study to use an objective time-motion analysis method in conjunction with HR monitoring to assess the physical demands of referees during competitive rugby union match play. The main results suggest that rugby union referees are subjected to moderate running demands and that the ability to perform high-intensity movements is reduced in the last part of the game.

PRACTICAL APPLICATIONS

The assessment of the external (i.e., running demands) and internal (i.e., HR responses) load imposed during the competition is the first step preceding the design of specific conditioning programs in rugby union referees. Referees' running performance is reduced throughout the match. Although the causes of this reduction in running performance remains unknown, fitness training of rugby union referees should aim to develop appropriate levels of high-intensity, intermittent running performance to promote fatigue resistance in the final 30 minutes of a game.

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Table 1. Sprinting performance results obtained during matches in rugby union male referees ($n = 30$).*

Variables	Halves: First half	Halves: Second half	Effect size
Number of sprints	11.2 ± 6.8	9.0 ± 5.4†	0.41 ± 0.16
Maximal speed ($km \cdot h^{-1}$)	24.1 ± 2.0	23.5 ± 1.7	0.27 ± 0.32
Maximal sprint distance (m)	38.7 ± 16.3	33.1 ± 13.1	0.33 ± 0.37
Average sprint distance (m)	15.4 ± 3.3	15.6 ± 4.3	0.05 ± 0.57
Average time of sprint (s)	2.53 ± 0.5	2.64 ± 0.68	0.25 ± 0.56
Time between consecutive sprints (s)	3.42 ± 2.4	4.49 ± 3.09†	0.47 ± 0.23

*Data are mean ± *SD*.
†Significant differences between halves ($p < 0.05$).

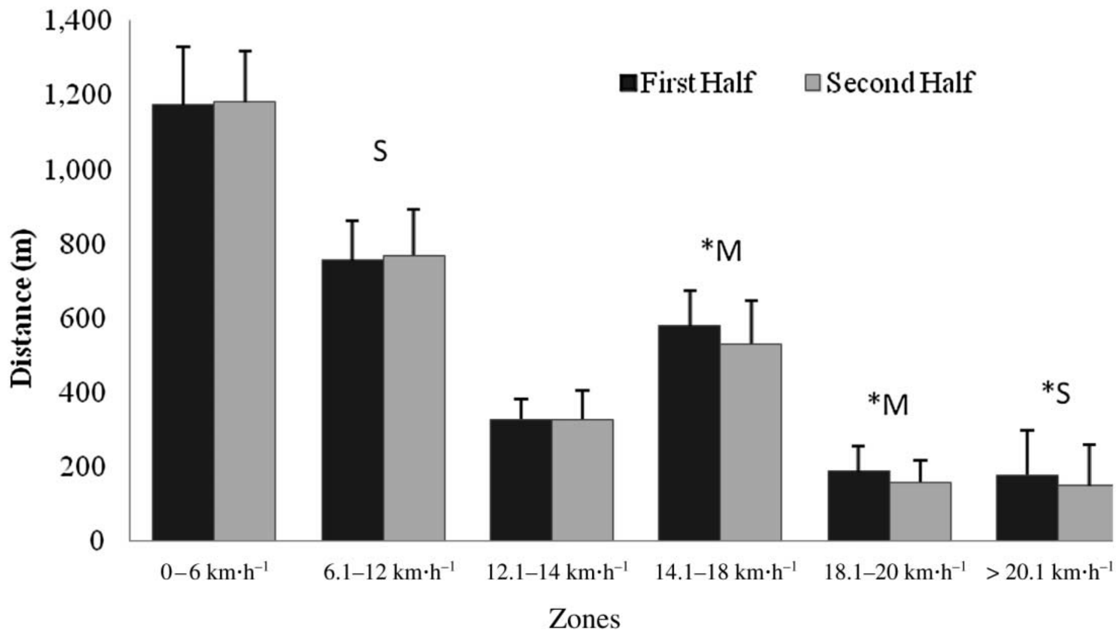

Figure 1. Match running profile during each half for men's rugby union referees (n = 30). Distance in meters covered by referees in designated speed zones. *Significant difference between halves ($p < 0.05$). ES = effect size; S = small; M = moderate; L = large; VL = very large ES. Data are mean ± SD

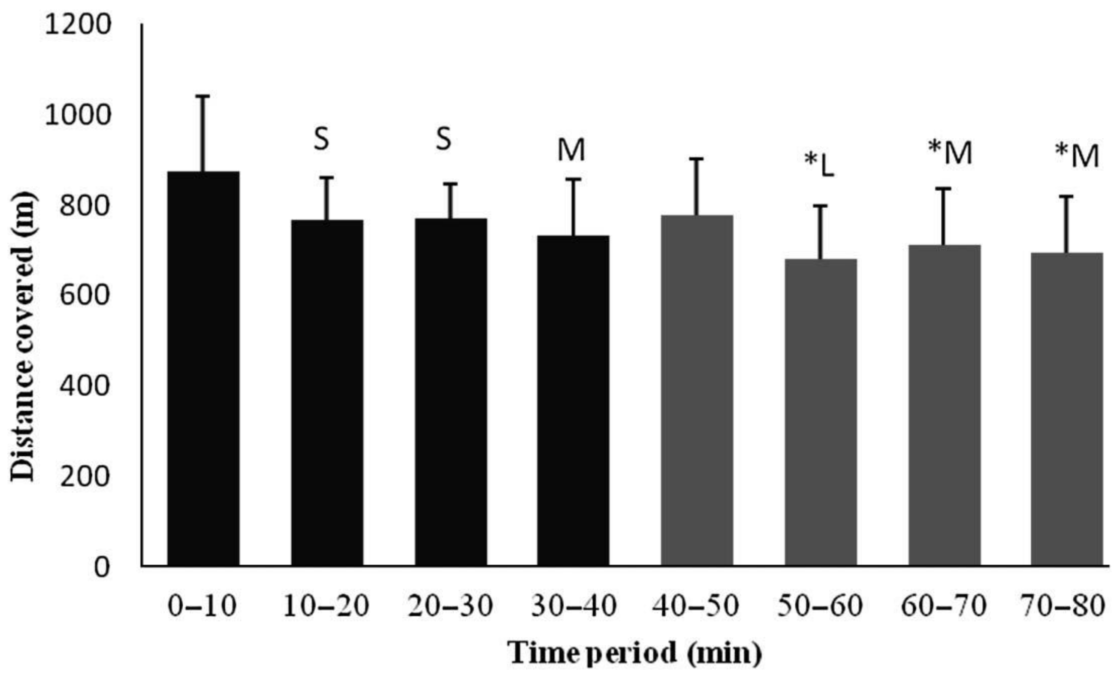

Figure 2. Relative total distance travelled over each 10-minute period during match play in men's rugby union referees (n = 30). *Significant difference to 0 to 10-minute period ($p < 0.05$). ES = effect size; S = small; M = moderate; L = large; VL = very large ES. Data are mean ± SD.

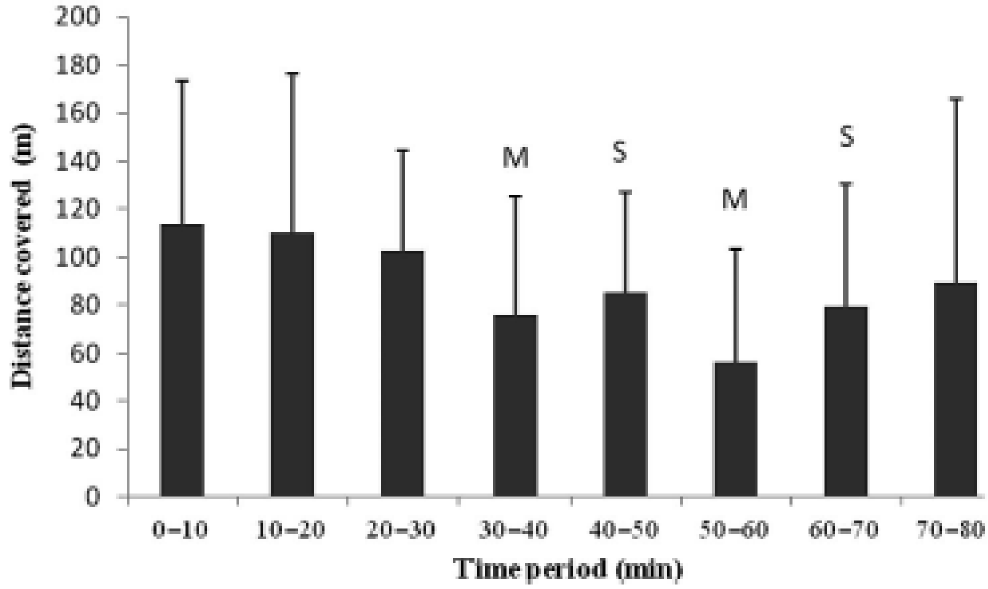

Figure 3. Relative high-intensity distance travelled over each 10-minute period during match play in men's rugby union referees (n = 30). ES = effect size; S = small; M = moderate; L = large; VL = very large ES. Data are mean ± SD.

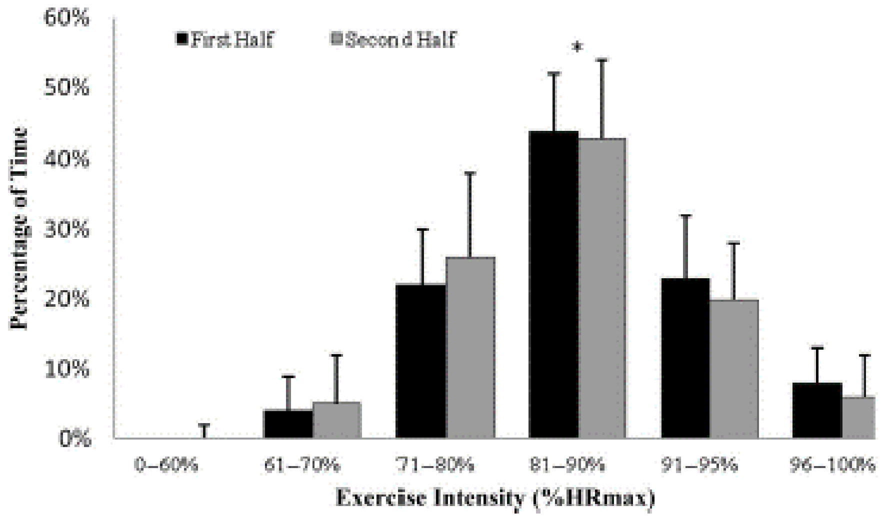

Figure 4. Percentage of playing time spent at each exercise intensity zone during each half in men's rugby union referees (n = 30). *Significant higher than any other intensity zone ($p < 0.05$). ES = effect size; S = small; M = moderate; L = large; VL = very large ES. Data are mean ± SD.