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HEART RATE DYNAMIC AND STRUCTURE OF RUNNING ACTIVITIES IN BIH PREMIER LEAGUE FOOTBALL REFEREES DURING MATCHES AND FITNESS TESTING

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Original research:

Abstract
The aim of this research was to determine the levels and structure of cardiac load via heart rate dynamic (HR) and movement activities of football referees during matches of the Premier League of Bosnia and Herzegovina and fitness testing. Additionally, the study aimed to investigate whether there are differences in the physical preparedness levels of Premier League referees and whether there are differences in running structures between referees in the Premier League of Bosnia and Herzegovina and those in the top European leagues. Heart rate data during the SDS test suggested higher time spent in Zone 4 (81-90% HR max) compared to other zones. Heart rate data during matches mainly was in third and fourth intensity zones ($p<0.001$). Significantly higher heart rate load (HR load) was present during the SDS test compared to matches. High intensity runs war significantly lower compared to moderate and low intensity ($p<0.05$) and distances covered during matches were marginally lower compared to the observed in elite level league. Physical demands placed on football referees, particularly in the Premier League of Bosnia and Herzegovina, necessitate top-notch physical conditioning and overall health, and the research indicates that these referees exhibit physical characteristics similar to elite-level referees, with notable differences in intensity zones during matches and the SDS test, highlighting the suitability of the SDS test for evaluating their situational performance, while also highlighting the need for further improvement in their aerobic capacity.

Key words: high intensity, speed, matches, heart rate load

Introduction

Football is a dynamic game intertwined with a high number of intense runs, sprints, accelerations, and decelerations, as well as tactical and technical demands (Mohr et al., 2022). In today's football, the focus is placed on genetic and physical predispositions, not only for football players but also for referees (Krustrup et al., 2009). The rules of football are constantly changing, directly impacting the dynamics of refereeing during matches (Krusturp et al., 2009; Weston et al., 2004; Aguirre-Loaiza et al., 2020). During the match, it was noted that the referees displayed notable aerobic energy generation consistently and experienced significant instances of anaerobic energy utilization. Additionally, it was discovered that their capacity for high-intensity running (HIR) and backward running declined as the match progressed.

Physical demands on referees in professional football are immense, and physical predispositions and performances are crucial for effective officiating. The essence and perception of decision-making on the field are closely linked to adequate physical fitness (Mascarenhas et al., 2009).

Analyzing the movements of referees during matches has practically equated, and in some instances increased, their activity and efforts compared to players. Referees cover more than 11 kilometers during matches and often reach speeds exceeding 13 km/h (Castagna et al., 2007). Specifically, this high-intensity performance level sustained over ninety minutes is the best indicator of the physical preparedness of football referees. In contrast to the head referees, assistant referees cover an average of 7 to 8 kilometers per match.

In modern football, it is estimated that referees run from 9 to 13 kilometers. During these activities, heart rates reach between 85 and over 90% of their maximum. Of the total distance covered, 10 to 18% involves high-intensity running activities. Blood lactate concentrations range from 4 to 5 mmol/L. Castagna et al. (2007), in a comparative study, found minimal differences in these activities between referees and midfield players in professional teams, especially in terms of the distance covered over ninety minutes. However, referees have a slightly lower VO2 max value compared to players.

Additionally, Krustrup et al. (2009) suggested that international match officials can sustain a noteworthy level of high-intensity running as the game approaches its conclusion. Conversely, low-intensity running and unconventional running activities decrease during the game. Additionally, it was observed that the extent of high-intensity running is linked to the officials' ability to stay in sync with the game's pace.

The aim of this research was to determine the levels and structure of cardiac load and movement activities of football referees in matches of the Premier League of Bosnia and Herzegovina. Additionally, the study aimed to investigate whether there are differences in the physical preparedness levels of Premier League referees and whether there are differences in running structures between referees in the Premier League of Bosnia and Herzegovina and those in the top European leagues. The hypothesis was that there are no significant differences in the running structure itself.

Methods

Participants

The study involved a total of N=23 elite male football referees from Bosnia and Herzegovina (age: 35.9±3.70 years; height: 185.2±5.82 cm; body mass: 80.8±6.42 kg) (Table 1). All participants were healthy, without injuries in the previous 6 months, and officiated in the Premier League of Bosnia and Herzegovina during the 2021/22 season. The inclusion criteria included having a consistent refereeing record (minimum 5 matches). The procedures were conducted in accordance with the Helsinki Declaration and with ethical approval from the Faculty of Sport and Physical Education.

Procedures

The research represents a cross-sectional study. Data collected from the PLBiH 2021/2022 season were used to elucidate cardiac load in different intensity zones and analyze the movement structure and activities of football referees. Data collection was performed in two phases: i) data obtained from regular physical fitness testing of football referees for cardiac activity and load parameters, and ii) data obtained from the analysis of matches for cardiac activity and load parameters, as well as the analysis of movement structure. A total of 74 matches were analyzed in a sample of 23 football referees (Table 1). Data were originally collected and systematized using the Polar Flow application, which is mandatory for referees to use along with wearing a heart rate monitor watch (Polar M430). Data obtained using GPS technology for measuring are valid, objective, and highly accurate in accordance with the time dynamics of the matches and activities. Individual load intensities were determined based on the maximum heart rate of each referee, which was determined during testing.

Table 1. Sample characteristics (N=23).

	Mean	SD
Age (years)	35.9	3.70
Body height (cm)	185.2	5.82
Body mass (kg)	80.8	6.42
Body mass index (kg/m^2)	23.4	1.71
Fat percentage (%)	13.92	2.78

SD – Standard deviation;

Heart Rate Activity and Load during the SDS Fitness Test

Heart rate activity and load during fitness testing were recorded during regular fitness tests before the start of the season using the Single-Double-Single (SDS test) recommended by UEFA. The test aims to assess the aerobic endurance capacities of referees as it is structurally similar to the movement patterns during a match. The test intensity engages both the anaerobic and aerobic energy systems. Prior to the test, participants warmed up for 10 minutes, which included static and dynamic stretching and coordination exercises. Before the actual test, each participant performed 2 sprints of 40 meters with a 90-second break in between. The SDS test consisted of 3 sets of intermittent shuttle runs with a 72-second break between sets. Each set included 5 runs, with each run consisting of: 1. Running 60m in 12 seconds followed by a 6-second break. 2. Shuttle run 72m – 36 meters with a cone turn in 16 seconds followed by a 6-second break, and 3. Running 60m in 12 seconds followed by a 24-second break (Scheme 1). The variables used for research purposes from the Polar watch were: Maximum heart rate (HR max) – The value of the maximum heart rate, average heart rate (HR avg) during the test, Recovery 60″ - the difference between the maximum heart rate value and the heart rate value after the first minute following the test, heart rate load (HR load) expressed as a percentage of the value of time-based heart load in specific intensity zones.

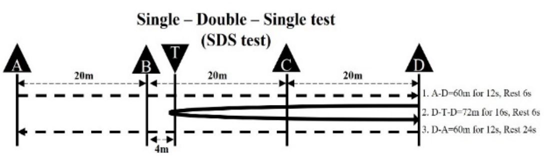
A smaller time period spent in high-intensity load zones suggests better physical preparedness of referees. The percentage of time spent in load zones relative to the total test time: Zone 1 (50-60% HR max), Zone 2 (61-70% HR max), Zone 3 (71-80% HR max), Zone 4 (81-90% HR max), and Zone 5 (91-100% HR max).

Heart Rate Load and Activity during Matches

Heart rate load during matches was analyzed in a total of 74 competitive PLBiH matches. Each match was analyzed individually during play (without halftime breaks). Data were recorded for each referee individually through the Polar Flow application, and the results were measured using the Polar M430 watch (Henriksen et al., 2019), which tracks movement activity and heart rate through GPS and optical HR sensor. The GPS device's accuracy for measured distances is ±2% (manufacturer's technical specification) with a data collection frequency of 50Hz.

Research variables related to heart rate load and movement activity include: Total distance covered (km), Maximum running speed (km/h), Distance covered in Zone 1 (50-60% HR max) (km), Distance covered in Zone 2 (61-70% HR max) (km), Distance covered in Zone 3 (71-80% HR max) (km), Distance covered in Zone 4 (81-90% HR max) (km), Distance covered in Zone 5 (91--100% HR max) (km), Distance covered at a speed of 3.0-7.0 km/h, Distance covered at a speed of 7.1-11.0 km/h, Distance covered at a speed of 15.1–19.0 km/h, and Distance covered at a speed >19.1 km/h.

Sheme 1. Single – Double – Single (SDS) running test procedure.



Statistical Analysis

All data were presented as measures of central tendency (arithmetic mean) and distribution variability (standard deviation). For all variables, maximum and minimum result values were shown, as well as the range of results. Data were prepared and organized in a pre-prepared Excel matrix (Microsoft Corp.).

Normality of distribution was assessed using the Shapiro-Wilk test. Differences in the distance covered at different intensities were determined using ANOVA with LSD post hoc tests for pairwise comparisons. The difference in heart rate load (HR load) between the SDS test and matches was assessed using the T-test. Data processing and graphical representation were carried out using Excel software (Microsoft Corp.). The level of statistical significance was set at 95%.

Results

Table 2 presents the heart rate loads, percentage, and duration in intensity zones during the execution of the SDS test. The average value of HR max was 177±7.7 b.p.m, with a range of 164-193 b.p.m, and the average heart rate HR avg was 156±10.7 b.p.m. The average value of recovery after 60 seconds was 35±6.1 b.p.m (19±6%). The average heart rate load was 77.7±7.8%. Statistically significantly more time during the SDS test was spent in Zone 4 (81-90% HR max) 45.71±13.89% ($F=3.45$ (df(4,71); $p<0.001$) compared to the other zones.

Table 2. Heart rate and structure of aerobic load zones during SDS running test in referees PLBiH (N=23).

	Mean	SD	Range	Max	Min
HRmax (b.p.m)	177	7.73	29	193	164
HRavg (b.p.m)	156	10.7	50	173	123
Recovery 60'' (b.p.m)	35	6.1	25	48	23
Recovery 60'' (%)	19	6	15	29	14
HR load %	77.71	7.79	25.2	90.85	65.65
Zone 1 (50-60%HRmax) *(%)*	2.07	1.67	5.32		
Zone 2 (61-70%HRmax) *(%)*	10.15	3.45	13.89		
Zone 3 (71-80%HRmax) *(%)*	22.07	15.37	61.67		
Zone 4 (81-90%HRmax) *(%)*	45.71	13.89	61.18		
Zone 5 (91-100%HRmax) *(%)*	20.00	20.10	60.20		

SD – Standard deviation;

Table 3 displays the heart rate loads, percentage, and duration in intensity zones during matches. The average value of HR max was 178±4.5 b.p.m, with a range of 171-188 b.p.m, and the average heart rate HR avg was 143±4.7 b.p.m. The average heart rate load was 64.3±7.5%. Statistically significantly more time during matches was spent in the third (71-80% HR max) 29.4±12.5% and fourth (81-90% HR max) 35.8±14.3% intensity zones ($p<0.001$) compared to the other zones.

Table 3. Heart rate and structure of aerobic load zones during matches in referees PLBiH (N=23) (sample of 74 matches).

	Mean	SD	Range	Max	Min
HRmax (b.p.m)	178	4.47	17	188	171
HRavg (b.p.m)	143	4.7	14	151	137
Zone 1 (50-60%HRmax) *(%)*	9.50	6.10	17.00	17.00	0.00
Zone 2 (61-70%HRmax) *(%)*	15.30	5.80	20.00	28.00	8.00
Zone 3 (71-80%HRmax) *(%)*	29.40	12.50	37.00	51.00	14.00
Zone 4 (81-90%HRmax) *(%)*	35.80	14.30	43.00	57.00	14.00
Zone 5 (91-100%HRmax) *(%)*	10.10	8.00	26.00	27.00	1.00
HR load %	64.30	7.50	22.60	74.60	52.00

SD – Standard deviation;

Table 4 presents the running structure during official PLBiH matches. The total distance covered was 8.473±0.531m with a range of 7.710 to 9.270m. The maximum achieved running speed during the match was 24.62±2.27 km/h, ranging from 21.8 to 28.8 km/h. Statistically significantly, the longest distance covered during matches was in the fourth (81-90% HR max) heart rate zone, at 3.472±1.518 m (p<0.001) compared to the other zones. The longest distance covered during matches was statistically significantly in the first running intensity zone (3.0-7.0 km/h) at 3.078±0.453 m (p<0.001) compared to the other zones.

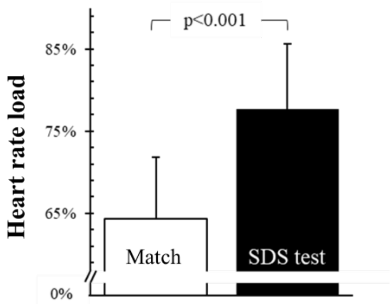
Tabela 4. Structure of running activity during matches in referees PLBiH (N=23) (sample of 74 matches).

	Mean	SD	Range	Max	Min
Total distance(km)	8.473	0.531	1.56	9.27	7.71
Max speed (km/h)	24.62	2.27	7.0	28.8	21.8
Zone 1 (50-60%HRmax) (km)	0.231	0.221	0.61	0.61	0.00
Zone 2 (61-70%HRmax) (km)	0.961	0.678	1.98	2.40	0.42
Zone 3 (71-80%HRmax) (km)	2.696	1.147	3.44	4.62	1.18
Zone 4 (81-90%HRmax) (km)	3.472	1.518	4.75	5.80	1.05
Zone 5 (91-100%HRmax) (km)	1.108	0.969	3.25	3.30	0.05
Running velocity 3.0-7.0 km/h (km)	3.078	0.453	1.46	3.64	2.18
Running velocity 7.1-11.0 km/h (km)	2.548	0.183	0.52	2.82	2.30
Running velocity 11.1-15.0 km/h (km)	1.550	0.355	1.20	2.39	1.12
Running velocity 15.1-19.0 km/h (km)	0.675	0.267	0.89	1.30	0.45
Running velocity >19.1 km/h (km)	0.281	0.21	0.56	0.64	0.08

SD – Standard deviation;

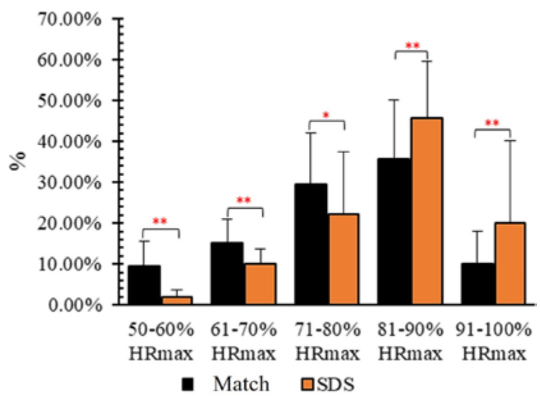
Graph 1 shows a significant difference (p<0.001) in heart rate load (HR load%) between the SDS test and matches, with heart rate load being higher during the SDS test (>13.4%).

Graph 1. Comparative differences in heart load (HR load%) durring match (n=74) and SDS running test in football referees (n=23).



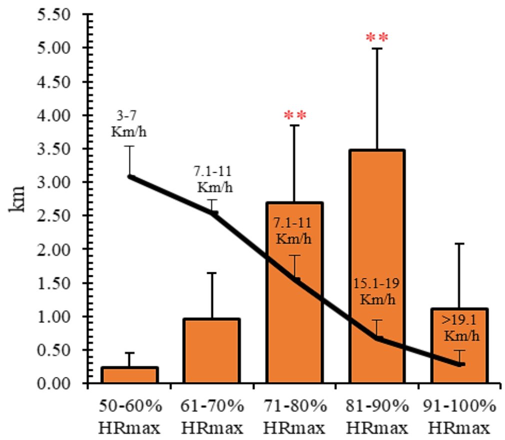
Graph 2 illustrates a significant difference in the structure of the percentage of heartbeats in different intensity zones (% of HR max) between the SDS test and matches.

Graph 2. Comparative differences in the percentage of time spent in each heart rate intesitiy zone (%HRmax) durring match (n=74) and SDS running test in football referees (n=23)



Graph 3 demonstrates comparative differences in the distance covered in different heart rate zones and in different running intensity zones during matches. Referees covered the longest distances in the third and fourth heart rate zones (p<0.001).

Graph 3. Comparative differences between the structure of running activity: Total distance in HR intesitiy zones (%HRmax) VS Total distance in running velocity intensites (RV) during the match (n=74) in football refrees (n=23).



Discussion

Based on the results, we will discuss three segments of the findings: 1) the analysis of heart rate values during matches and the test, 2) the analysis of movement structures in aerobic load zones, and 3) the analysis of time spent in heart rate zones during matches and the SDS test. Aerobic training for the development of aerobic fitness is commonly conducted at 70% to 80% of HR max. Maximum heart rates were similar to those reported in the study by Krustrup and Bangsbo in 2001. Average heart rates expressed as a percentage of the peak heart rate achieved during the match, as previous studies have shown that referees reach 95-100% of their maximum heart rate during high-level games, which was similar to our results (Helsen & Bultynck, 2004; Krustrup & Bangsbo, 2001).

When determining intensity zones in addition to HR max, it is necessary for individuals to know their lower and upper pulse rate limits. In Table 2, we can observe the intensity zones referees spent the most time in during the SDS test. Referees spent the majority of their time in Zone 4, which is often referred to as the submaximal oxygen uptake zone, accounting for 45%, or an average of 64 seconds. Zone 1 had the smallest percentage of time spent in intensity due to its low-intensity nature, and the game's structure does not allow for low and moderate-intensity activities. The average HR max does not differ significantly from the average during the test, indicating the suitability of using the SDS test to assess referees' physical fitness and its appropriateness. An analysis of heart rate load results (HR load %) reveals that it is higher during the SDS test than during matches. The intensity of the SDS test is higher compared to the matches, with referees spending more time in Zone 5 during the test than during matches. During matches, the heart rate load goes up to 65%, while in the test, it reaches 76%, indicating an 11% higher average load during the test compared to matches. Referees spent the most time in the fourth heart rate zone, both during matches and the SDS test. Furthermore, this study unveiled substantial variances among individuals in the extent of high-intensity running (HIR) accomplished by referees.

The average total distance covered by PLBiH referees during matches is 8.4 km per game, which represents a lower level compared to elite-level matches where the average is between 10 and 12 kilometers. It is evident that the greatest distance covered is in the fourth heart rate zone, with the highest distance covered occurring in the running intensity zone 1, from 3.0 to 7.0 kilometers per hour. These results suggest a significant discrepancy in aerobic fitness levels and the ability of referees to perform high-intensity activities. It is important to consider limiting factors such as the quality of the matches played, the rhythm, speed, dynamics of the game, and weather conditions.

Birinci et al. estimated that referees who train in high-intensity zones with a training structure similar to actual matches experience faster recovery. According to Castagna, C. et al. (2007) and Mascarenhas et al. (2009), who conducted research to determine differences between referees and midfield players, referees are estimated to cover distances ranging from 9 to 13 kilometers, which is significantly higher compared to the results of our study where distances covered ranged from 8 to 10 kilometers. This difference could be attributed to the fact that the distances covered may be reduced through strategic positioning and the anticipation of forthcoming events (Castagna, Abt, D'Ottavio, & Weston, 2005; Weston, Castagna, Impellizzeri, Rampinini, & Breivik, 2010).

The results from Castagna and colleagues indicate that the time spent in Zone 4 is similar to our study, but the distance covered is significantly shorter, indicating a reduced capacity of PLBiH referees to work in a high-intensity regime. A significant difference between PLBiH referees and elite-level referees is that elite referees spend approximately 18% of their match time in the fifth heart rate zone, while PLBiH referees spend 10% of their match time in Zone 5. The intensity in Zone 5 HRmax is significantly less represented in PLBiH referees, as is the total distance covered in running intensities above 19 km/h and sprinting distances at speeds above 25 km/h.

Research conducted by Karabalcik et al. (2020) addresses the physical capacity and decision-making. The study involved 5 younger and 5 older referees. According to the results, physical fitness parameters and the quality of decisions are better in the 5 older referees. This could serve as a recommendation to include decision-making tasks in our training programs to reduce error rates.

The results of this research can assist novice referees in better understanding the effort and physical demands of a refereeing role in football.

Conclusion

The physical demands on football referees during matches require excellent physical preparation and good health. Based on the research conducted, it can be concluded that PLBiH referees have physical characteristics like referees in the elite category. The most significant indicators are the differences in intensity zones shown both in matches and in the SDS test. This suggests that the SDS test is suitable for assessing the situational efficiency of our referees. It is also important to note that, on average, referees in the

Premier League of Bosnia and Herzegovina cover between 8 and 10 kilometers per match, while referees who officiate in European competitions or other high-level matches cover between 10 and 12 kilometers per match.

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Submitted: *23.04.2023.*
Accepted: *25.05.2023.*