PHYSIOLOGICAL LOAD OF REFEREES DURING BASKETBALL GAMES

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Original scientific paper
UDC: 612:796.015.54:796.015.572:796.323.2(497.5)

Abstract:

The objective of this study was to establish physiological loads elite basketball referees sustain during competitive games. Thirty-one referees (age: 33.35±5.17 years, body mass: 88.04±7.47 kg, height: 186.37±5.40 cm), all classified as A-list referees of the 1st Croatian Basketball League, were subjected to progressive spiroergometric testing on the treadmill in order to determine the anaerobic threshold (V-slope method). The referees were monitored electrocardiographically for the establishment of physiological load during competitive games. Their heart rate (HR) was measured during the games using a *POLAR* RS400 cardiotachometer. The level of physiological load was determined according to individual work intensity zones that had been determined using laboratory testing for each subject separately. The lowest intensity zone of load was below 79% of HR at the ventilatory threshold, the following zone included HRs between 80 and 89% of HR at the ventilatory threshold, then between 90 and 100% of HR at the ventilatory threshold, whereas the highest zone was above the HR at the ventilatory threshold. The time each subject spent in a particular intensity zone was determined and expressed as a percentage of the total game time. The average HR during a game was 131.52±9.10 bpm, that is, 77.34±6.05% of the HR at the anaerobic threshold. It was established that the referees spent 50% of the total game time in zones of high aerobic load (extensive and intensive aerobic zone), whereas if we only examine the time during the quarters, then this percentage amounts up to 60%. The referees spent only 1-2% of the total game time in the anaerobic energetic process load zone. There were no significant differences between younger and older referees in physiological load they sustain during the games. These findings indicate basketball referees must possess a high aerobic capacity to withstand physiological load during a basketball game.

Key words: *heart rate, aerobic capacity, anaerobic threshold*

Introduction

In modern-day basketball games there is an extremely high level of activity during the entire duration of 40 minutes. Both male and female players are required to have well developed cardio-respiratory and energy supplying capacities as well as basic and specific motor abilities in order to play the game. The following motor abilities prevail in basketball and characterize energetically the activity: explosive power required for starts, short-distance sprints and maximal defensive and offensive rebounds; coordination while performing specific motor assignments; agility during quick changes of direction; neuromuscular reaction time and the speed at which all these movements are performed. A high aerobic capacity reduces the level of fatigue and provides for a faster recovery during short breaks throughout the entire game, whereas the anaerobic capacity ensures necessary endurance for high-intensity repetitive activity performances (Jukić, Milanović, & Vuleta, 2005; Huciński, Łapszo, Tymański, & Zienkiewicz, 2007; Narazaki, Berg, Stergiou, & Chen, 2009; Matković, 2010).

Basketball referees are an integral part of a basketball game. Their job is to regulate behaviour of players and other participants in the game through the implementation of basketball rules. In order to make quality decisions, the referees must be at the right place, so that they have a good overview of the situation on the court, which requires their excellent physical condition, visual perception, mental ability, the ability to apply their knowledge, focus and willingness, as well as the ability to make quick decisions (Jungebrand, 2006).

Understanding the intensity of physiological load to which basketball referees are subjected during a basketball game enables a higher level of quality in planning and programming their train-

ing process. The referees who undergo a better physical conditioning and motor preparation will be able to observe players and situations during a game with less difficulty, which will in the end have a positive effect both on the regularity of the competition and on the development of basketball in general (Rupčić, Matković, Knjaz, Baščevan, & Rodić, 2011).

However, there are very few research studies examining basketball referees, with contradictory findings regarding physiological loads (Leicht, 2004, 2008).

In 2004 Leicht conducted a study on one subject during three men's basketball games in a national competition (duration of the game: 4x12 minutes, officiating mechanics: three referees) and one women's basketball game in a national competition (duration of the game: 4x10 minutes, officiating mechanics: two referees). The results of the study led him to the conclusion that basketball referees were subjected to a high level of physiological load, as well as that there were no statistically significant differences in the level of loading both regardless of whether they were officiating in a men's or women's game, and regardless of the type of officiating mechanics (two-men or three-men officiating). Namely, the average HR during all four games was 130 bpm, and the referee spent 63% of the total game time in the intensity zone with physiological load over 70% of the maximum HR. In 2008, the above mentioned author conducted another study on a sample of seven referees. Each referee officiated between two and four basketball games, all of them using a two-men officiating mechanics. Based on the results he obtained, Leicht (2008) concluded once again that basketball referees were subjected to an activity of a high intensity level; however, this time with somewhat higher average HR results (150±18 bpm), as well as a higher load intensity (79±9% of the maximum HR).

In 2013 Borin et al. performed a study on a sample of 18 referees during 12 official games of the Brazilian Basketball League and they arrived at the conclusion that during a basketball game referees covered a distance of between 4.02 and 6.17 km, as well as that this distance significantly increased as the competition entered its final stage (final play-offs). Upon analysing the results from individual quarters of the game, they concluded that there were significant differences in the distances covered by the referees. They found that a greater distance was covered in the fourth quarter (1.71 km) in relation to the third (1.44 km) during the final play-off games.

The intensity of physiological load was determined according to HR that were registered as a percentage of the maximum HR, as well as according to the blood lactic acid concentration. The average HR results during the total game time were between 71.66±10.40 and 78.39±6.52% of the HR_{max}, depending on the competition stage that the game was played in, and between 70.07±9.48 and 79.94±7.12% of the HR_{max} when analysing the results according to the individual quarters of a game. Based on the results obtained during this study, Borin et al. (2013) concluded that the HR values, which were registered as percentages of the maximum HR, decreased significantly as the game was coming to its end. However, this happened only in the final stages of the competition (semi-final and final games). The results of the blood lactic acid concentration showed no significant differences regardless of the game periods or the competition stage, and they were on average between 2.24±0.69 and 3.37±0.67 mmol.

Lončar, Dežman and Licen (2004) found that referees covered an average distance of 5,921 m during a basketball game. The intensity of the movements varied throughout the game and it attained approximately 85 and 90% and approximately 70 and 80% of the maximal HR and the maximal oxygen consumption, respectively.

Thus the main aim of this research was to determine physiological loads of basketball referees during the official games of the 1st Croatian Basketball League. Another goal of this study was to explore whether there were any differences between the physiological loads of the younger and older referees when officiating basketball games.

Methods

Subjects

The sample of examinees consisted of 31 basketball referees who were classified as A-list referees of the 1st Croatian Basketball League in the season 2008/2009. The referee A-list is determined by the Association of Croatian Basketball Referees and it is compiled each year according to the referees' results from the previous season. The average age of the referees was 33.35±5.17 years, and they all had over seven years of experience in officiating at the highest national competition level. For the purpose of determining the differences in physiological loads between basketball referees according to their age, the sample was divided into two subsamples. One subsample (n=16) – younger referees – consisted of referees aged between 26 and 32 years (29.62±1.85 years), while the other subsample (n=15) – older referees – included referees aged 33 years and older (37.33±4.56 years), taking the average age as a border. All referees provided a written informed consent after a brief but detailed explanation as to the purpose, benefits and risks involved in this study. The Ethics Committee of the Faculty of Kinesiology, University of Zagreb, approved the research study.

Testing procedures

The research was conducted in two stages. The first stage was focused on laboratory measurements, that is, on the evaluation of energy supply capacities of the examined referees. The second stage of the research consisted of field measurements, that is, the measurements of physiological load during the actual official basketball games of the 1st Croatian Basketball League (one game for each referee).

Aerobic capacity of the referees was determined using a progressive spiroergometric test on the treadmill with a constant inclination of 1.5% while speed was increased by 1 km/h every minute. After a detailed explanation of the testing protocol on the treadmill, each examinee received a face mask of an appropriate size and sticky electrodes for telemetric heart rate recording were placed on his chest. According to the protocol, during the first minute of the test, the examinee stood still on the treadmill, while the cardiorespiratory parameters were recorded. Then the examinee started walking at a speed of 3 km/h, while each following minute the treadmill speed was increased by 1 km/h (progressive load test). The test continued to the point of exhaustion. As the examinee was running on the treadmill, a breath-by-breath analysis of the pulmonary gas exchange was performed using a Quark monitor (Cosmed, Italy) and oxygen consumption was calculated. In this manner the maximal oxygen uptake was measured, as well as the ventilatory threshold which was determined by using the V-slope method. The ventilatory threshold was expressed as the HR at the threshold (Beaver, Wasserman, & Whipp, 1986; Walsh & Davis, 1990). The ventilatory threshold was used to determine the work intensity zones, for each referee individually. The lowest intensity zone was below 79% of the HR at the ventilatory threshold, the following zone included heart rates between 80 and 89% at the ventilatory threshold, then between 90 and 100% of the HR at the ventilatory threshold, whereas the highest zone included the rates above the HR at the ventilatory threshold.

During a basketball game the HR was measured using *POLAR* cardiotachometers, model RS400 (Finland). The devices recorded the HR in 5-second intervals and after the game the data was analysed using the Polar Pro Trainer 5 ® programme application. The cardiotachometers were placed on the examinees prior to their warm-up (a chest strap which served as a transmitter, and a wrist watch which served as a receiver). However, they were not activated until the beginning of the basketball game and they were disconnected at the end of the game, measuring HRs across all live and stoppage times.

The games were monitored by official and professional observers who noted all time breaks during the games using a handheld stopwatch. The total time of each quarter of each game was recorded, as well as the total time of each game, including all active and passive time periods.

Statistical analysis

Data analysis was performed using the STATISTICA software package for Windows, 10th edition, and the following parameters were calculated for each variable: arithmetic mean (Mean), standard deviation (SD), minimum value (MIN) and maximum value (MAX). The normality of distribution for each variable was tested using the Kolmogorov-Smirnov test. The differences in physiological loads between the younger and the older referees during the games were tested using independent samples *t*-test and analysis of variance (the level of statistical significance was set at $p<.05$).

Results

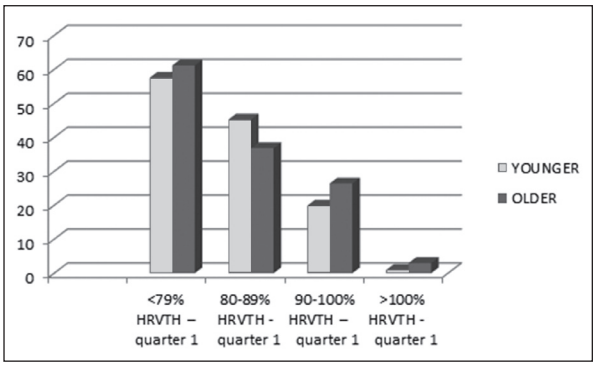
The results of HR recordings, shown in Table 1, indicate that the referees were officiating while being in the zones of high aerobic intensity, that is, in both the extensive aerobic zone (80-89% HR_{VTH}) 35.07% of the total game time, and in the intensive aerobic zone (90-100% HR_{VTH}) 16.77%. Basketball referees spent an average of 47.03±22.78% of the total duration of the game in the lowest intensity zone (recovery zone) in which HRs go up to 79% of the HR at the ventilatory threshold. They spent an average of 1.12±2.58% of the total duration of the game in the anaerobic zone.

During the total duration of a basketball game (including the intervals of game among quarters; 2x2 min + 1x15 min) the referees spent 50% of the time in the zone of loading which requires high aerobic endurance. If only the time of the four periods (with no pauses between them) of the game is considered, the percentage spent in the abovementioned (aerobic high-intensity) zone is over 60%.

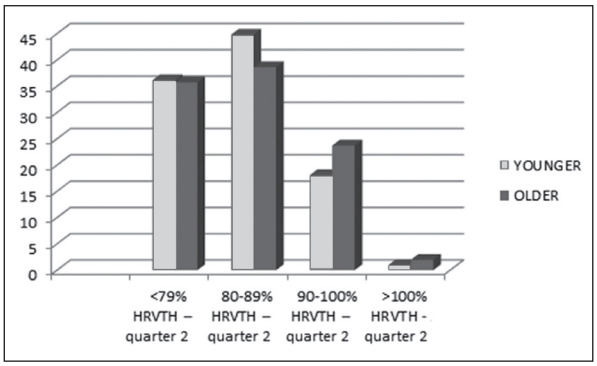
Table 1. Average time spent in each intensity zone during a basketball game (in percentages)

Zone of intensity	1st quarter	2nd quarter	3rd quarter	4th quarter	Total game
<79% HR_{VTH}	33.79±24.54	35.94±26.73	37.26±28.38	40.88±30.66	47.03±22.78
80-89% HR_{VTH}	41.20±14.44	41.80±12.58	40.71±16.19	40.58±18.24	35.07±10.29
90-100% HR_{VTH}	23.07±23.08	20.79±20.89	20.52±21.28	17.82±21.09	16.77±16.49
>100% HR_{VTH}	1.93±4.57	1.46±3.65	1.50±3.49	0.71±2.06	1.12±2.58

Legend: HR_{VTH} – heart rate at ventilatory threshold



1a First quarter



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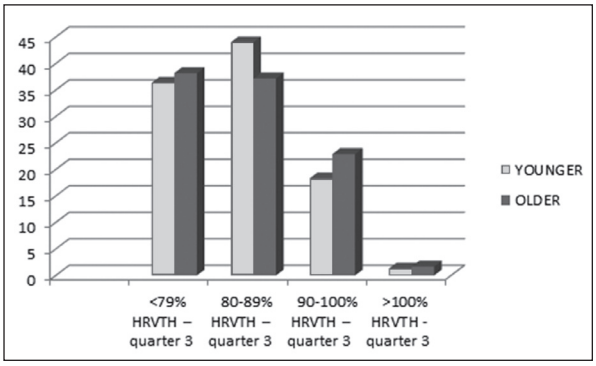
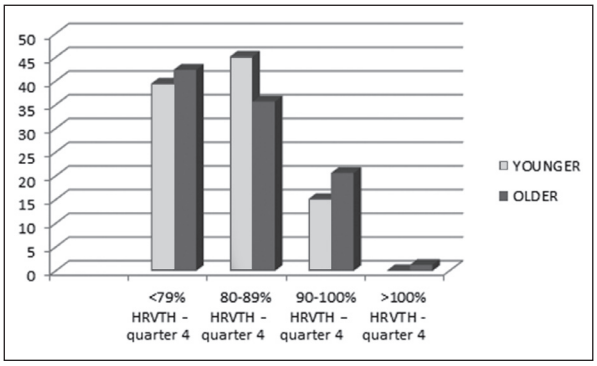
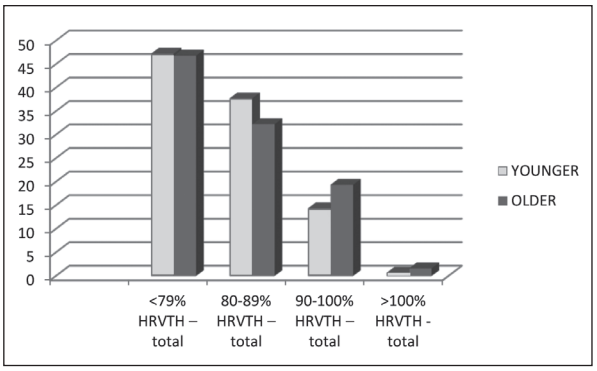


1c Third quarter



1d Fourth quarter



1e Total game time

Figure 1. Percentages of time spent in individual zones of physiological load

The average HR during all four periods of basketball game (including all active and passive game time, that is, live and stoppage time), without taking into consideration the intervals of play between quarters, was 139.63±9.19 bpm, that is, 74.86±4.57% of the maximum HR and 82.09±5.78% of the HR at the ventilatory threshold (Table 2).

The average HR during an entire basketball game, including the intervals of play between quarters (total time), was 131.52±9.10 bpm, that is, 70.52±4.80% of the maximum HR and 77.34±6.05% of the HR at the anaerobic threshold.

The percentages of the time spent in different zones of physiological load for younger and older referees are presented in Table 4 and Figure 1. There were certain minor differences throughout the match, in all quarters of the game; however, none of them were statistically significant (p=.865), as can be seen from the results of the ANOVA presented in Table 3, as well as from the *t*-test in Table 4.

Table 2. Basic statistical parameters of variables assessing the physiological load on referees during a basketball game

ID	Unit	Mean	SD	MIN	MAX
HR $\overline{X}_{\text{half time}}$	bpm	**109.48**	9.02	85.00	129.00
$HR_{\text{min. half-time}}$	bpm	89.25	9.70	**64.00**	106.00
$HR_{\text{max. half-time}}$	bpm	144.19	14.20	118.00	186.00
HR $\overline{X}_{\text{(L-S)}}$	bpm	**139.63**	9.19	125.00	164.75
$\%HR_{\text{max(L-S)}}$	%	**74.86**	4.57	65.56	85.61
$\%HR_{\text{VTH (L-S)}}$	%	**82.09**	5.78	70.21	93.78
HR $\overline{X}_{\text{(total)}}$	bpm	**131.52**	9.10	117.28	156.14
$\%HR_{\text{max(total)}}$	%	**70.52**	4.80	60.49	81.97
$\%HR_{\text{VTH (total)}}$	%	**77.34**	6.05	64.79	89.80

Legend: $\overline{X}$HR – average heart rate; $\%HR_{max}$ – the total percentage of maximum heart rate; $\%HR_{VTH}$ – the total percentage of heart rate at ventilatory threshold; HR_{min} – the minimum value of heart rate; HR_{max} – the maximum value of heart rate half-time - interval of play of fifteen minutes between the second and the third quarter; L-S – live time and stoppage time; total – live time and stoppage time including the intervals of play between each period (quater)

Table 3. The results of the analysis of variance for the differences between younger and older referees in physiological load they sustain during the games

Test	Value	F	Effect df	Error df	**p**
Wilks	0.468	0.567	20	10	**.865**

Table 4. Independent samples t-test

Variables	YOUNGER	OLDER	t-value	df	p	F-ratio variances	p variances
<79% $HR_{\text{VTH –quarter 1}}$	57.57	61.19	-0.53	29	**.59**	1.54	.41
80-89% $HR_{\text{VTH –quarter 1}}$	45.29	36.84	1.67	29	**.10**	1.14	.80
90-100% $HR_{\text{VTH –quarter 1}}$	19.92	26.44	-0.78	29	**.44**	1.04	.92
>100% $HR_{\text{VTH - quarter 1}}$	0.92	3.01	-1.28	29	**.21**	4.56	.00
<79% $HR_{\text{VTH –quarter 2}}$	36.16	35.73	0.04	29	**.96**	1.50	.44
80-89% $HR_{\text{VTH –quarter 2}}$	44.79	38.61	1.38	29	**.17**	2.19	.14
90-100% $HR_{\text{VTH –quarter 2}}$	18.07	23.71	-0.74	29	**.46**	1.00	.99
>100% $HR_{\text{VTH – quarter 2}}$	0.98	1.96	-0.73	29	**.46**	3.35	.02
<79% $HR_{\text{VTH – quarter 3}}$	36.40	38.19	-0.17	29	**.86**	1.33	.58
80-89% $HR_{\text{VTH – quarter 3}}$	44.01	37.21	1.17	29	**.24**	1.07	.88
90-100% $HR_{\text{VTH – quarter 3}}$	18.34	22.93	-0.59	29	**.55**	1.62	.35
>100% $HR_{\text{VTH – quarter 3}}$	1.32	1.69	-0.29	29	**.77**	1.92	.22
<79% $HR_{\text{VTH – quarter 4}}$	39.49	42.39	-0.25	29	**.79**	1.11	.83
80-89% $HR_{\text{VTH – quarter 4}}$	45.16	35.70	1.47	29	**.15**	1.24	.68
90-100% $HR_{\text{VTH – quarter 4}}$	15.17	20.66	-0.71	29	**.47**	2.30	.11
>100% $HR_{\text{VTH – quarter 4}}$	0.17	1.27	-1.50	29	**.14**	31.11	.00
***<79%* $HR_{\text{VTH – total}}$**	47.23	46.81	0.05	29	**.95**	1.63	.35
***80-89%* $HR_{\text{VTH – total}}$**	37.73	32.24	1.50	29	**.14**	1.36	.55
***90-100%* $HR_{\text{VTH – total}}$**	14.37	19.35	-0.83	29	**.41**	1.54	.41
***>100%* $HR_{\text{VTH – total}}$**	0.67	1.62	-1.02	29	**.31**	5.45	.00

Discussion and conclusions

Basketball referees are an integral part of a basketball game, as their assignment is to regulate behaviour of players through the implementation of basketball rules. This study examined physiological loads imposed on basketball referees during a basketball match.

Out of the total duration of a basketball game, the referees spent over 50% of the time in intensity load zones which require high aerobic endurance. When considering only the time during the four periods, without the intervals of play between them, this percentage of time spent in aerobic high-intensity zones was over 60%.

During the total time of a basketball game the referees spent an average of 35.07±10.29% in the extensive aerobic zone, and an average of 16.77±16.49% of time in the intensive aerobic zone. In these zones of intensity the characteristic HR values were between 130 and 160 up to 180 bpm, depending on the values of the aerobic and anaerobic ventilatory thresholds. These intensity zones represent the activities during which an organism can maintain a stable lactate concentration in the body using its buffering mechanisms. Blood lactate values in these intensity zones range between 2 and 4 mmol/l.

Basketball referees spent an average of 47.03±22.78% of the total duration of a basketball match in the lower intensity zone, that is, in the recovery zone (<79% HR_{VTH}). In this intensity zone the activities of the referees were below the anaerobic threshold for which the concentration of blood lactate varies between 0 and 2 mmol/l.

The referees spent only 1.12±2.58% of the total duration of a basketball game in the anaerobic intensity zone in which the anaerobic energy processes are manifested, that is, in the intensity zone in which HR exceeds the value of the heart rate at the ventilatory threshold.

Upon analysing the results obtained during individual quarters of the basketball games, the conclusion can be made that the referees spent most of their time in the high-intensity aerobic zones, that is, in the extensive and intensive aerobic zone. The referees spent an average of between 30 and 40% of the total duration of each period in the low intensity zone, that is, in the recovery zone, in which the HR level reaches up to 130 bpm (Table 1).

Lower HR values of basketball referees during individual quarters of a basketball match may be associated with certain interruptions in a match, such as the communication with the officials at scorer's table after personal fouls have been decided, then free-throw performances, time-outs, player injuries, substitutions, etc. (Borin, et al., 2013).

It is interesting to note that the HR values of referees did not go below the values recorded during rest periods, not even during the interval of play between the two half-times (Table 2). The same situation was noted in basketball players as well (McInnes, Carlson, Jones, & McKenna, 1995), however, with higher average HR values.

The average HR during a basketball game, without the intervals of play between periods, was 139.63±9.19 bpm, that is, 74.86±4.57% of the maximum HR and 82.09±5.78% of the HR at the ventilatory threshold. If we examine the entire game including the intervals of play between quarters, then the average HR was 131.52±9.10 bpm, that is, 70.52±4.80% of the maximum HR and 77.34±6.05% of the HR at the ventilatory threshold, which roughly corresponds to the results of recent studies in which the average heart rate of referees was 130 bpm, with an average of 73% of the maximum HR (Leicht, 2004; Borin, et al., 2013) (Table 2).

Based on the results of this research, we can conclude that while officiating a basketball game, the referees are exposed to an intermittent physical load during which the aerobic capacity functions as the primary energy supply system. In other words, the conclusion can be made that during a match, basketball referees demonstrate considerable aerobic energy consumption with occasional episodes of significant anaerobic engagement.

Based on the obtained results, it can be concluded that basketball referees are exposed to high physiological loads, however, well-prepared referees demonstrated no statistically significant changes when considering different periods of a match (Rupčić, Matković, B.R., Knjaz, Nedić, & Popek, 2012; Borin, et al., 2013). Our results are in consistence with the results obtained in other studies on physiological load of referees during basketball games (Leicht, 2004, 2008), as well as with the results obtained in other sports, such as football and rugby (Catterall, Reilly, Atkinson, & Coldwells, 1993; D´Ottavio & Castagna, 2001; Martin, Tolfrey, Smith, & Jones, 2005). The best football referees maintain their HR values between 85 and 95% of their maximum during a game (Catterall, et al., 1993; D´Ottavio & Castagna, 2001, 2002; Krustrup & Bangsbo, 2001; Weston & Brewer, 2002). Certain variations among findings are probably associated with the methods of determining the maximum HR (laboratory testing, evaluation according to the referees' age using conventional formulas HR_{max}=220 - age, or the highest measured HR during a game). In this manner Helsen and Bultynck (2004) concluded that during extremely important games (e.g. the European Championship finals) the average HR of the best referees was at 85% of HR_{max}, which was determined using different protocols (laboratory testing, trainings, HR during a game). These numbers clearly indicate that the referees' aerobic metabolism was actively involved, which was also confirmed in the direct measurement of the oxygen uptake during friendly games by

using the telemetry system K2, Cosmed (D'Ottavio & Castagna, 2002). These results showed that the referees reached the level of 68% of their individual VO_{2max} during one half-time of a game. After comparing these numbers with the estimated numbers which were obtained in the laboratory by using the relation between the HR and the oxygen uptake, they concluded that their evaluation predicted higher values (75%), that is, that they overestimated the oxygen consumption during refereeing.

While examining the physiological load of basketball referees with regard to their age, it was expected that the older referees would spend more time in lower intensity zones due to their greater experience as opposed to the younger referees (Eissmann & D'hooghe, 1996; Rupčić, et al., 2011; Rupčić, Matković, & Barbaros Tudor, 2011).

This proved to be true for the lowest intensity zone (<79% HR_{VTH}) during the first three quarters. However, when examining the results across the entire game, the mentioned difference was slightly lost in favour of the younger referees. The younger referees also spent more time than their older colleagues in the extensive aerobic zone (80-89% HR_{VTH}). Contrary to what was expected, the older referees spent more time in the intensive aerobic zone (90-100% HR_{VTH}), as well as in the anaerobic zone (>100% HR_{VTH}). This situation can also be accounted for with the selection process of referees for different games, which is carried out by official commissioners. For top-level games, which are more demanding and of higher intensity, commissioners tend to choose referees with more experience, as they usually have better grades.

The conclusion can be made that the reason why older referees demonstrate higher intensities than younger referees arises from the fact that they probably officiate a larger number of high intensity games, such as games in the final phases of different competitions. It is precisely the same results obtained in past studies which pointed to the fact that basketball referees cover larger distances during the games as individual stages of the competition came to an end, and that the intensity of their physiological load, which is estimated on the basis of HR results, demonstrated a tendency towards progressive growth, although not a statistically significant one (Borin, et al., 2013).

The results obtained in this study show that basketball referees require high aerobic capacity in order to withstand the physiological loads during basketball games. However, a well-developed aerobic capacity is not required only in order to decrease the load on the cardiovascular and respiratory systems, which arises from the intensity of officiating a basketball game, but also in order to enable a faster recovery of the organism during a very short break, such as time-outs during periods or intervals of play between the first and the second, or the third and fourth quarters. If referees possess a well-developed aerobic capacity, their HR will stabilize faster and it will be closer to the values during breaks. Ultimately, this faster recovery will probably result in a higher level of concentration and a more effective monitoring of the situation in continuation of a match.

With regard to the fact that during this study all referees officiated only one game each, future studies should examine a larger number of games in order to arrive at somewhat more objective conclusions on load intensity, as well as on the differences in physiological load between younger and older referees. Likewise, in addition to HR values, upon determining the intensity of physiological load, certain other values should also be taken into consideration, such as: blood lactic acid concentration, the distance covered, the referees' manner of locomotion (acceleration, changes of direction, etc.), and so on.

According to the results regarding the level of physiological load on referees during a basketball match, that is, based on the time they spent in each intensity zone (extensive aerobic zone – 35.07%, and intensive aerobic zone – 16.77%), it is recommended that the basketball referees' training process should focus on the medium and high aerobic load zones in order to enhance their physical preparedness.

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Submitted: October 15, 2013
Accepted: September 18, 2014

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