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**ORIGINAL ARTICLE**

# The Effect of Physiological Load during Matches on the Quality of Refereeing in Handball Referees

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## ABSTRACT

**Background.** Referees are an integral part of every handball match which is considered a high-intensity activity and they need to follow the action as close as possible to avoid mistakes in their decisions. **Objectives.** This research aimed to determine the physiological loads of referees during handball matches and whether a higher physiological load during the match has a significant effect on the quality of refereeing. Also, RPE was tested to determine if referees are aware of loads during the match. **Methods.** The subject sample consisted of 32 handball referees in Premier Croatian handball. The first phase of research was conducted in the laboratory with functional abilities tests and the second phase was the measurement of physiological loads and quality of refereeing on official matches. **Results.** The correlation of physiological loads (time above anaerobic threshold zone) and quality of refereeing showed no significant correlation ($R=0.25/R^2=0.06/p<0.18$), while RPE estimations of referees correlate with measured physiological demands during matches ($r=0.55$, $p<0.05$). Physiological loads of handball referees during the match is a high-intensity activity with an average energy expenditure of 1025.37±210.19 kilocalories. **Conclusion.** Referees are exposed to high physiological loads during handball matches, but there is no correlation with the quality of refereeing measured in time above the anaerobic threshold zone. Referees should conduct programmed training to increase their level of functional abilities with special emphasis on increasing anaerobic capacity which is not satisfactory along with their lactic acid tolerance.

**KEYWORDS:** ***Physiological Stress, Anaerobic Threshold, Energy Expenditure, Referee Performance.***

## INTRODUCTION

In modern handball, the basic rules of the game have changed and have affected the speed, the number of attacks, the transformation in the game, and the overall pace of the game (1, 2). As a direct consequence of changing the rules of the game, the preparatory period of the attack is reduced which has led to more dynamic, faster, and more sophisticated tactics in the game (3). Following the rule which allows a fast restart of the game after the goal was scored by the attacking team, it contributed to the higher physical requirements of the players (2), as well as referees (4) whose physiological loads during the game could be higher than the physiological loads of the players during the match (5). The overall quality of refereeing must be consistent throughout the match and should not decrease (6). The lack of physical preparation of referees may be a limiting factor, so referees must be at a level that avoids fatigue and physical exhaustion during matches which prevent proper decision-making (5). Physiological loads of referees are very high during handball matches (7), and other team sports, and also they are correlated with the rank of competition (8-11) and this is the reason why referees need to increase their indicators of

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maximum abilities to be able to cope with all the requirements of handball match (12, 13). Handball referees have multiple tasks during a match which are much easier to perform if they are physically prepared and do not need to concentrate on their physical disadvantages. Thus, referees can concentrate on more important and relevant events during the match with a decrease in anxiety level and risk of making mistakes (14-16). Also, the overall quality of refereeing must be consistent throughout the match and should not decrease due to lack of physical preparation of referees as physiological loads of handball referees are high during the whole match with no differences between halves (6) The same conclusions were found in study of basketball referees where authors concluded that there is no difference in physiological loads between two halves, neither quarters of the match (17).

After basic training in national federations, the best referees get the appropriate knowledge and training in international federations which helps them improve the knowledge and quality of their refereeing (technique). The Group of authors pointed out that by achieving a top level in refereeing, referees not only raise the volume of training but also introduce additional practical activities that further raise their level and general knowledge of refereeing, unlike at the beginning of their career when referees are mostly concentrated almost exclusively on fitness preparation (18).

The perception of exertion is an important indicator of an individual's degree of physical strain, and the inventor of the Borg scale stated that perceived exertion is the single best indicator of the degree of physical strain (19). Ratings of perceived exertion (RPE) have been used in many studies with different varieties of exercises in the laboratory, the field, and also in many different groups of individuals where they show accurate loads of subjects (20), mostly athletes which have the linear connection of heart rate during intense activities and their ratings of perceived exertion (21). The relationship between subjective loads (RPE) and objective loads during matches (heart rate frequency) will be determined in official handball matches of top-level competition, as it hasn't been studied before.

The main aim of this research is to determine the physiological loads of referees during handball matches and whether a higher physiological load during the match (time in the match spent above the anaerobic threshold) has a significant effect on the quality of refereeing. As a partial aim of the study, the relationship between ratings of perceived exertion (subjective loads) and the heart rate frequency of handball referees during matches (objective loads) will be determined.

## MATERIALS AND METHODS

**Ethics Committee Approval.** This study was approved by the ethics committee of the Faculty of Kinesiology, University of Zagreb (87/2020) undertaken in compliance with the Helsinki Declaration. All of the participants signed written consent expressing their willingness to proceed with all the testing for this research.

**Participants.** The sample of this research was all 32 handball referees (100%) in the top-level Croatian handball league (age 34.29±6.20 years, height 184.20±5.87 centimeters, body mass 91.25±10.45 kilograms and body mass index 26.91±2.47 kg/m²). Referees are selected each year according to three elimination criteria on official seminars before each half of a season: 1. Grades which evaluate their performance during the previous competition year; 2. Morphological characteristics (with certain height referees have the maximum allowed body mass) and 3. Functional abilities tests. Ten referees are also on the list of international referee federations. Six pairs have European handball federation badges, while four have International handball federation badges.

**Procedure.** The study design was conducted in two phases. The first phase of research was the testing of functional abilities in the laboratory with ergospirometry on the treadmill (HP Pulsar 3P, Cosmos, Nußdorf, Germany). Before the progressive load test on the treadmill, subjects carried out the same protocol of warm-up which lasted approximately 20 minutes (dynamic stretching, basic running, and running with the change of speed, intensity, and direction, static stretching). After the warm-up test was conducted in standard microclimatic conditions (closed and ventilated room with 18-21°C) which are established by the official protocol. The computer system along with the accompanying device (Quark b2, Cosmed, Rome, Italy) displays on the screen all the data from every subject numerically and graphically in real-time (which means all parameters were monitored all visible all the time). Continuous monitoring of ventilation-

metabolic indicators is displayed on the computer screen after the analog-digital signal has been converted for each breath-by-breath cycle gathered through a breathing mask (7301 Eagle 1 Mask, Hans Rudolph, USA). The test protocol is standard and begins with the subject standing at the place and breathing through the respiratory mask. After one-minute subject starts to walk at 3 km/h for 2 minutes and the speed increases every minute for 1 km/h at a constant incline of 1%. At an approximate speed of 8 km/h, subjects start to run constantly until they can't track the speed of the treadmill anymore or have limiting factors or contraindications to stop the test before its end. After ergospirometry on the treadmill, results were used to determine individual intensity zones for subjects. In this paper, a TRIMP training zones model was used which was developed by Edwards and has five heart rate zones (22). Zones are divided into five classes according to the percentage of the maximum heart rate which was measured in the laboratory during tests: 1. Recovery zone 50-60%; 2. Extensive aerobic zone 61-70%; 3. Intensive aerobic zone 71-80%; 4. Anaerobic threshold zone 81-90%; 5. Maximum oxygen uptake zone ≥91%. The anaerobic threshold was individually detected with (already used in many pieces of research) reliable V-slope method (23) by monitoring the trend in the ratio of exhaled carbon dioxide and oxygen uptake (a point above the aerobic threshold where an increase of carbon dioxide production is steeper to oxygen uptake).

The second phase of the study was measuring physiological loads during official matches of the Croatian Premier Handball League. During these matches, referees had under their official shirt monitoring device which measured their heart rate and watches on wrist Polar RS400 (Polar, Kempele, Finland) which collected all the data from the transmitter. Referees were quality-wise supervised and evaluated during the match by official supervisors of the Croatian Handball Referees Association. Supervisors are experienced former referees, educated individuals with extremely high-level handball rules, and refereeing management knowledge (re-testing every 6 months). Indirectly, official supervisors of the match participate in the game management and at the end of the match he evaluates referees' pair performance, which will later be used as criteria for the quality of refereeing, and they are the only competent professionals who can evaluate referee performance during official matches. Energy expenditure during matches was calculated with a heart rate monitor device that referees wore during the match (Polar RS400, Polar, Kempele, Finland). Before the match, all the devices are calibrated on personal laboratory results (age, height, resting heart rate, and maximum heart rate) which are used for precise energy expenditure estimation.

After the match referees were questioned about their subjective opinion of the maximum load during the match which is known as a rating of perceived exertion (RPE). A significant correlation between RPE in incremental exercises (percentage of heart rate reserve r =0.89 & r=0.87; and percentage of maximum oxygen uptake reserve r=0.88 & r=0.90) and interval exercises with measures of intensity (percentage of heart rate reserve r=0.085 & r=0.84 and blood lactate concentration r=0.74 & 0.78) was already proved (24) and therefore will be used in this research due to easy application and reliability. Referees rated their load and exposure during the match on a scale from 0 to 10 (the same used during progressive ergospirometry test), with 0 meaning extremely easy and 10 meaning maximum load.

**Data Analysis.** For all used variables central and dispersion parameters, arithmetic mean (Mean), and standard deviations (SD) were calculated using the statistical software Statistica (ver. 13.4). Kolmogorov-Smirnov's test was used to check the normality of distribution and the maximum deviation of the empirical and theoretical relative cumulative rate (Max D). The correlation of physiological loads (independent variables) and quality of refereeing (dependent variable) was tested with multiple regression analysis tests and the level of significance was set at $p < 0.05$.

## RESULTS

For laboratory tests and field measuring of subjects, all the basic statistical parameters were calculated: arithmetic means, minimum value, maximum value, standard deviation, skewness and kurtosis of distribution, and a maximum deviation of the empirical and theoretical relative cumulative frequency (Table 1). Results obtained during official matches were measured and collected with the telemetric system for heart rate monitoring which referees carried under official

match shirts along with a rating of perceived exertion after the match.

Basic statistical parameters of five intensity zones according to the percentage of maximum heart rate are presented in Table 2. They are the results of field measurements during official matches.

According to the results of the regression analysis (Table 3). The simple correlation coefficient is 0.25 and the significance coefficient $p$ = 0.18. No statistically significant correlation was found between the time spent in the match above the anaerobic threshold and the quality of refereeing.

**Table 1. Descriptive Statistical Parameters of Laboratory Testing, Physiological Loads during the Match, and Ratings of Perceived Exertion after the Match, N = 32**

| | Unit | AS | MIN | MAX | SD | SKEW | KURT | MAX D |
|---|---|---|---|---|---|---|---|---|
| **Laboratory testing before the match** | | | | | | | | |
| **HR rest** | bpm | 69.48 | 50 | 97 | 11.59 | 0.79 | 0.55 | 0.24 |
| **HR max** | bpm | 186.97 | 171 | 203 | 8.56 | -0.14 | -0.44 | 0.89 |
| **HR ant** | bpm | 176.17 | 161 | 190 | 8.10 | -0.22 | -0.49 | 0.13 |
| **%HR max ant** | % | 94.27 | 86.01 | 98.84 | 2.93 | -1.32 | 2.86 | 0.25 |
| **$VO_2$max** | ml/min | 4082.76 | 3120 | 4747 | 417.68 | -0.40 | -0.54 | 0.09 |
| **R$VO_2$max** | ml/min/kg | 45.35 | 38.06 | 61.02 | 6.13 | 1.10 | 0.91 | 0-14 |
| **R$VO_2$max ant** | ml/min/kg | 41.06 | 32.62 | 52.74 | 4.92 | 0.61 | 0.19 | 0.09 |
| **Field testing during the match** | | | | | | | | |
| | | **AS** | **MIN** | **MAX** | **SD** | **SKEW** | **KURT** | **MAX D** |
| **HR mean** | bpm | 141.89 | 97.00 | 164.00 | 16.02 | -0.62 | 0.69 | 0.09 |
| **%HR max** | % | 75.86 | 56.73 | 92.00 | 7.94 | -0.01 | 0.49 | 0.17 |
| **%HR ant** | % | 80.58 | 60.25 | 98.18 | 8.47 | -0.04 | 0.32 | 0.14 |
| **HR min** | bpm | 102.30 | 75.00 | 137.00 | 13.32 | 0.30 | 0.95 | 0.08 |
| **HR max** | bpm | 167.89 | 117.00 | 193.00 | 16.93 | -1.09 | 1.62 | 0.14 |
| **ENE** | kcal | 1025.37 | 508.00 | 1378.00 | 210.19 | -0.06 | -0.01 | 0.18 |
| **ENErel** | kcal/kg | 11.30 | 5.08 | 18.07 | 2.60 | 0.08 | 1.08 | 0.11 |
| **Estimation after the match** | | | | | | | | |
| **RPE** | **1-10** | **5.00** | **3** | **7** | **1.20** | **0.38** | **-1.27** | **0.30** |

**HR rest:** resting heart rate; **HR max:** maximum heart rate; **HR ant:** heart rate at the anaerobic threshold; **% HR max ant:** the percentage of maximum HR at the anaerobic threshold; **$VO_2$max:** maximal oxygen uptake; **R$VO_2$max: r**elative maximal oxygen uptake; **RVO2 max ant:** relative maximal oxygen uptake at an anaerobic threshold**; HR mean:** average HR during the match; **%HR max:** percentage of maximum HR; **%HR ant:** percentage HR at the anaerobic threshold; **HR min:** minimum heart rate; **ENE:** energy expenditure; **ENErel:** relative energy expenditure per kilogram; **RPE: the** rating of perceived exertion

**Table 2. Descriptive statistical parameters of referees' intensity zones during handball match**

| Intensity Zone (% of HRmax) | AM | MIN | MAX | SD | SKEW | KURT | MAX D |
|---|---|---|---|---|---|---|---|
| **Recovery zone (50-60%)** | 15.87 | 0.00 | 98.90 | 22.99 | 2.34 | 5.93 | 0.27 |
| **Extensive aerobic zone (60-70%)** | 54.41 | 1.10 | 88.00 | 28.59 | -0.61 | -1.01 | 0.17 |
| **Intensive aerobic zone (70-80%)** | 25.06 | 0.00 | 92.70 | 26.79 | 1.12 | 0.29 | 0.21 |
| **Anaerobic threshold zone (80-90%)** | 3.12 | 0.00 | 25.40 | 7.14 | 2.34 | 4.32 | 0.38 |
| **Maximum oxygen uptake zone (90-100%)** | 1.58 | 0.00 | 27.00 | 5.57 | 4.16 | 18.11 | 0.46 |

**Table 3. Results of Multiple Regression Analysis – Influence of Physiological Loads (Time in the Match above Anaerobic Threshold) on Quality of Refereeing**

| R = 0.25 / $R^2$ = 0.06 / Adjusted $R^2$ = 0.03 / F(1.27) = 1.88 / $p$ < 0.18 / Standard Error = 3.82 | | | | | | |
|---|---|---|---|---|---|---|
| **N = 31** | **Beta** | **Std.Err. of B** | **B** | **Std.Err. of B** | **t (21)** | **P-Level** |
| **Intercept** | | | 71.06 | 0.78 | 91.10 | 0.00 |
| **%V anp** | q | 0.19 | -0.15 | 0.11 | -1.37 | 0.18 |

A statistically significant correlation was only found between average match heart rate frequency and ratings of perceived exertion scores (r = 0.55, $p$ < 0.05, n = 32). Age of referee, total experience in refereeing, or experience in refereeing at the highest rank don't have a significant correlation with ratings of perceived exertion.

During the match, referees wore a telemetric system for measuring heart rate frequency which was recorded as physiological load (Figure 2) before the match start (warm-up) and during the match (and break between periods of the match).

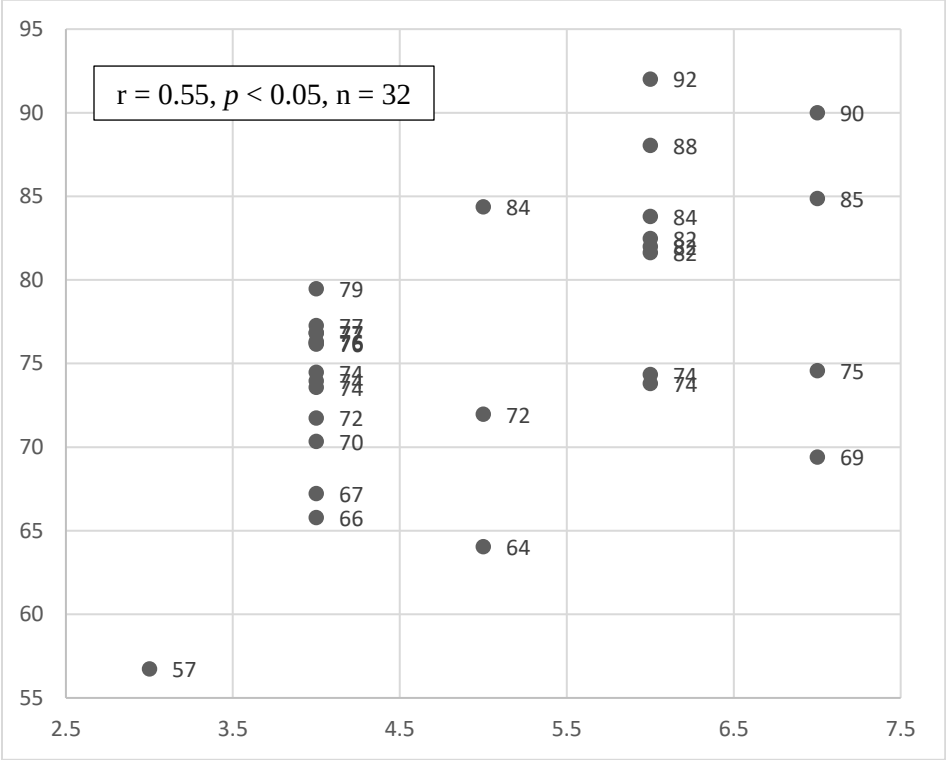


**Figure 1. Correlation between Average Match Heart rate Percentage (%HR max) and Ratings of Perceived Exertion**

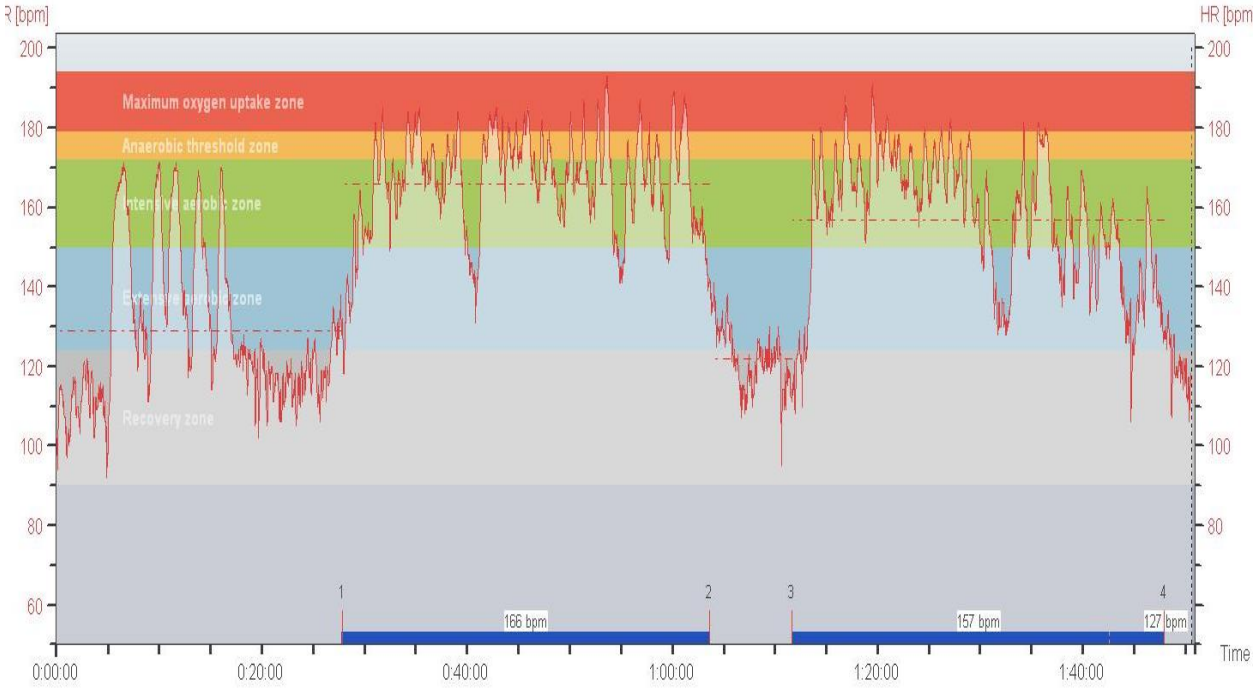


**Figure 2. Physiological Demands of Handball Referee during Match**

During the match, the referees spent 54.41% of the match time in the extensive aerobic zone, 25.04% in the intense aerobic zone, 15.87% in the recovery zone 3.12% in the anaerobic threshold zone, and 1.58% in the maximum oxygen uptake zone (Figure 3).

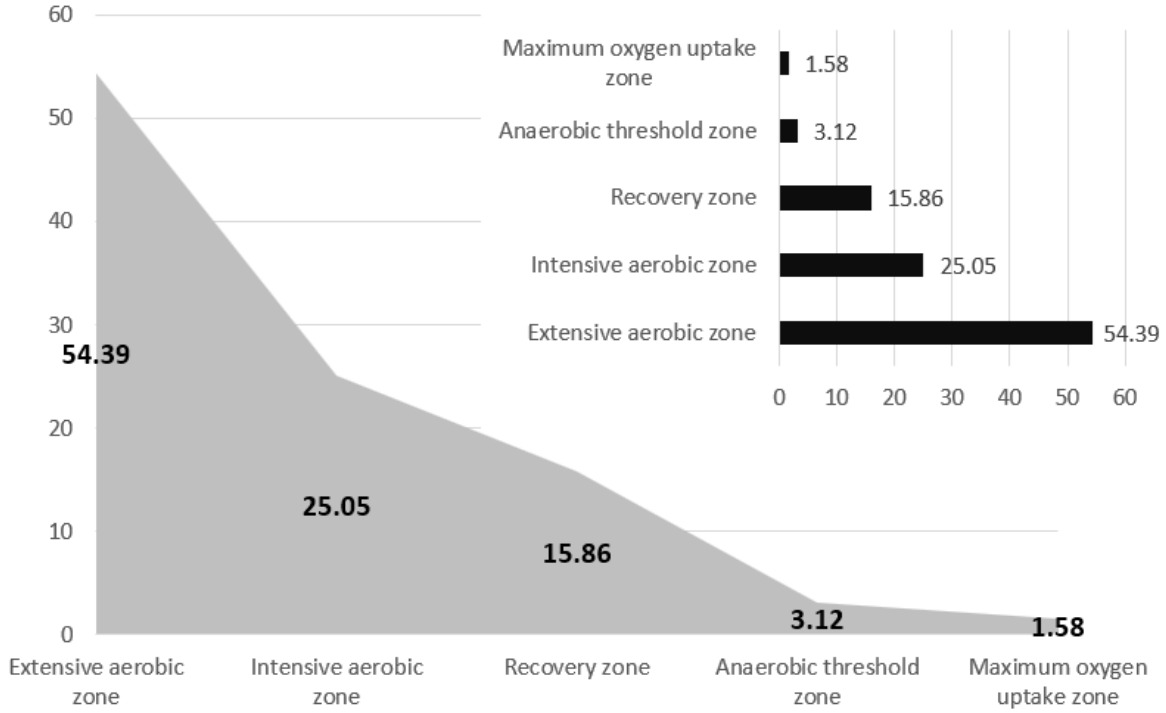


**Figure 3. Distribution of Time in Intensity Zones during Official Matches**

## DISCUSSION

According to analyzed data of the physiological loads during matches, the average heart rate was 141.89±16.02 beats per minute. In percentages, this is 75.86±7.94 of the maximum heart rate, which is higher than the results of a similar study (131±15 beats per minute or 68% of the maximum heart rate) of physiological loads in the Brazilian league (7) and Costa Rican handball referees (143.06±16.94 beats per minute) officiating U19 matches (25). Studies with football and rugby referees' physiological loads show significantly higher average heart rates during matches, which can be described due to a much larger playing field and more difficult conditions to move on rough terrain compared to handball which is played indoors (26-28). The highest average heart rate during matches is 164 beats per minute and the lowest is 97 beats per minute which are extremely high variability. It is interesting to note that the lowest average frequency had the highest-rated referee, while the highest average frequency had one of the worst-rated referees. The minimum frequency during matches is 75 beats per minute, while the highest is 193 beats per minute, and according to the frequency itself it can be concluded that the referee was in the zone of maximum loads, and this frequency shows extremely high physiological loads to which referees are exposed to during handball matches. In a monitoring example of a handball referee during a match (Picture 1), the referee spends on average most of the match time in an intensive aerobic zone (71% - 80% of maximum heart rate frequency). Some parts of the match are above the referees' anaerobic threshold and some are also in the maximum oxygen uptake zone which can be dangerous in decisive matches where one decision can have an impact on the outcome of the match (6). Decision-making and cognitive abilities are reduced when the referee (or athlete) reaches and goes above the anaerobic threshold (29-31), and this must be avoided as the probability to make the wrong decision in those conditions is high.

Similar results as in this research were obtained in a study conducted on basketball referees (32) where authors presented the average heart rate during all four periods of basketball match (including active and passive game time) was 139.63±9.19 beats per minute which is 74.86±4.57% of the maximum heart rate and 82.09±5.78% of the heart rate at the anaerobic

threshold. Choi and Roh also conducted physiological loads research on amateur football referees during matches where they found a mean heart rate in the first and second half of 150 and 148 beats per minute respectively, and a maximum heart rate of 177 and 175 beats per minute (33). These findings are higher than in this research, and this can be explained by the already mentioned differences between handball and football at the beginning of the discussion.

After performing an ergospirometry the load zones were individually determined. The zones are divided into five groups according to the percentages of the maximum heart rate that were earlier classified into percentage classes. In total, during the match, the referees spent the most time in the extensive aerobic zone, slightly more than half of the total match time, or 54.41%. In the research of Gutierrez-Vargas et al. referees spent most of the match in the intense aerobic zone with 34.82±24.14% and secondly in the extensive aerobic zone with 29.58±24.06% of total match time (25). The second dominant zone in this research was the intense aerobic zone in which referees spent exactly one-quarter of the total match time or exactly 25.04%. Given that the sum of aerobic zones gives almost 80% of the total duration of the match, it can be concluded that refereeing a handball match is a predominantly aerobic activity. Considering the type of energy expenditure during the match, the referees must have a well-developed aerobic capacity. Good aerobic capacity will allow referees to officiate with significant quality in dominant zones of the match, but will also help referees to quickly recover their heart rate during rest periods after more intense activities (32, 34). The third most represented zone is the recovery zone where the referees most often perform activities at the very beginning of the match or during short breaks in the match. Due to the above-mentioned optimal aerobic capacity, it is easier for the referees to reduce the frequency to the value of the recovery zone in which they spent 15, 87% of the total time in the match. Intensely hardest zones, anaerobic threshold zone, and maximum oxygen uptake zone should be minimized during the match. In the anaerobic threshold zone, referees spent 3.12%, while in the zone of maximum oxygen uptake, they spent 1.58% of the total active and passive duration of matches. This is a total of almost 5% in the last two zones compared to similar research where the sum of the last two zones is over 15% (25). Values are much higher than in this research, but they can be explained by the lack of experience of young referees who cope weaker with stress and pressure (4), and thus their heart rate is much higher during matches, especially conflict situations (35). During high loads reaching beyond the anaerobic threshold, the organism undergoes submaximal and maximal loads during handball matches. During these high intensities of activities, there is a decline in the performance of the organism, especially by referees with the concentration and technical performance of the refereeing (29, 30). The referees should conduct training to raise anaerobic capacity because of this important part of the match which is taking place in the highest load zones (36). Training prescription should consider intensities at anaerobic threshold speed (which was measured as 14 km/h at 91% heart rate max) targeting aerobic fitness development in elite officials (37). Referees don't have a good anaerobic capacity as they end their ergospirometry very quickly after passing the anaerobic threshold, and this is a result of performing only aerobic training during individual or preparations in pairs. Anaerobic zone mostly occurs at the end of the match or in unclear or doubtful situations in which referees must make decisions in a split second (35, 38), as one decision can decide the winner of the match (6, 9). These intervals are characterized by a decline in motor and functional abilities as well as cognitive abilities that are significant in referees, such as attention, concentration, and decision-making, even though it doesn't have a statistically significant impact on the quality of refereeing. To reduce the possibility of errors caused by these aspects of refereeing to a minimum, referees should conduct programmed training to increase their level of functional abilities with special emphasis on increasing anaerobic capacity under supervision or with the guidance of a professional.

Subjective estimation of referees' averages shows referees were feeling from easy to light hard, with a small range of their estimation of maximum loads during the match. Statistical analysis of the correlation between real physiological loads which referees experienced during matches and their subjective feeling of loads shows referees have a good estimation of

real loads during the match as they are statically significant. It can be concluded that the relationship between match heart rate and ratings of perceived exertion is a valid measure for referees' workloads during official matches (9). With loads during the match, other parameters such as the age of the referee, total experience in refereeing, or refereeing in the highest rank were tested for correlation and they don't have any significance with ratings of perceived exertion. Although in some cases it is seen that the rating of perceived exertion of maximum load during the match is not following the real physiological loads measured by heart rate measuring systems which could be counterproductive for referees' pre-season and mid-season preparation. This could be also considered as a limitation of referees' quality as they consider matches are not so demanding and they don't prepare individually enough to be on a level that allows them to follow matches and referee most of the match time in zones below the anaerobic threshold. As mentioned above, counterproductive because the most important and deciding situations happen during the highest loads in the match such as fast breaks, conflict situations (strong fouls, injury to players), pressure on referees (from players, officials, spectators), and most important wrong decisions of referees which they are aware during the match. Those decisions affect referees' physiological loads which increase their heart rate and the chance of making another wrong decision (repeatedly).

Energy expenditure during matches averaged 1025.37±210.19 kilocalories with a maximum measured expenditure of 1378 kilocalories, while the lowest measured value was 508 kilocalories. Nabli et al. conducted research on basketball referees during U19 Championship and they determined an average energy expenditure of 504.4±77.7 kcal (39). This is twice less than the results obtained in this study, which can be explained by the lack of pressure on referees from young players. Referees have better authority in younger age categories and regarding this, also their physiological loads are lower because the sum of both external (sprints, total distance covered, accelerations, changes of rhythm and pace, distance at certain velocities, …) and internal (physiological demands such as heart rate and ratings of perceived exertion) loads makes those matches less demanding than professional matches. In this study very interesting information which must be noted is that the highest energy expenditure during the match was scored by the highest-rated referee, while the highest was scored by one of the worst-rated referees. Considering that energy expenditure during the match is more than 1000 kilocalories it can be concluded that refereeing a handball match is a high-intensity activity. These data have been interpreted to make it easier to compare results with previous studies but given that not all subjects have the same body mass, it is considered better to use relative value for energy expenditure. The relative value of energy expenditure, i.e., expenditure per kilogram of a subject during matches was 11.30±2.60 kilocalories. The highest relative energy expenditure during matches is 18.07 kilocalories per kilogram, while the lowest calculated value is 5.07 kilocalories per kilogram. The tested hypothesis if there was a statistically significant correlation between higher physiological load during the refereeing (measured by time spent in the anaerobic zone) and quality of refereeing proves there is no statistically significant difference between the time spent above the anaerobic threshold and the quality of the refereeing. The percentage of time during a match spent in the anaerobic zone in the variability in which they exist does not discriminate in the way that some referees are more successful in the quality of refereeing. This is mostly down to the good selection of referees from the national association, and little variability of functional abilities between referees who are already selected as a homogenous group.

The study participants sample included one of the best handball referees in Europe (and, commonly, European handball referees are mostly officiating final matches of every major club or international competition), as Croatian handball referees are often in charge of European and World competitions finals (or final four) matches. The participant's sample is considered one of the main strengths of this study. The study has some limitations which could be considered in the next research such as tracking with GPS tracking systems and other devices for measuring the movement of handball referees during matches. Also, one of the rules during the research was to communicate with the referees as little as possible during the matches not to interfere with their focus on the match. Therefore,

lactate concentration levels were not measured during the handball periods, and it would be good to include lactate concentration level measures in future research.

## CONCLUSION

Physiological loads during handball matches are very high and constant throughout the whole match for the referees with an average energy expenditure of over 1000 kcal per match proving handball refereeing is high-intensity activity. Referees don't have good anaerobic capacity and tolerance on lactic acid as they end their ergospirometry test very quickly after passing the anaerobic threshold. This is a result of performing only aerobic training during individual or (mostly) preparations in pairs, but on the other side, the aerobic capacity of referees is satisfactory as aerobic energy processes are predominated (intense and extensive aerobic zone) during the handball matches. A higher physiological load during a match doesn't have a significant effect on the quality of refereeing, which can be described with an already selected population of the best referees.

## APPLICABLE REMARKS

- Referees don't conduct appropriate training for their anaerobic capacity which is very important as some of the most demanding and important match intervals occur in the anaerobic zone.
- These intervals are characterized by a decline in motor and functional abilities as well as cognitive abilities that are significant in referees, such as attention, concentration, and decision-making (even though it doesn't have a statistically significant impact on the quality of refereeing).
- To reduce the possibility of errors caused by these aspects of refereeing to a minimum, referees should conduct programmed training to increase their level of functional abilities with special emphasis on increasing anaerobic capacity under supervision or with the guidance of a professional.

## AUTHORS' CONTRIBUTIONS

*Study concept and design:* Belcic and Ruzic. *Acquisition of data:* Belcic and Krakan. *Analysis and interpretation of data:* Belcic and Krakan. *Drafting the manuscript:* All authors. *Critical revision of the manuscript for important intellectual content:* Belcic and Ruzic. *Statistical analysis:* Belcic. *Administrative, technical, and material support:* Belcic and Krakan. *Study supervision:* Ruzic.

## CONFLICTS OF INTEREST

The authors declare that they have no competing interests.

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