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Original Article

Analysis of the load intensity of female handball players during a match

ROMAN VALA[1], MARIE VALOVÁ[2], MARTINA LITSCHMANNOVÁ[3], PAVLA DRÁŽDILOVÁ[4]
[1] Institute of Physical Education and Sport, VŠB Technical University of Ostrava, Ostrava, CZECH REPUBLIC
[1, 2] Department of Computer Science, VŠB Technical University of Ostrava, Ostrava, CZECH REPUBLIC
[3] Department of Applied Mathematics, VŠB Technical University of Ostrava, Ostrava, CZECH REPUBLIC
[4] Department of Computer Science, VŠB Technical University of Ostrava, Ostrava, CZECH REPUBLIC

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Abstract:
Introduction: Heart rate (HR) is one of the easily available physiological indicators. Today, it is one of the most frequently used and exceptionally reliable load intensity analysis method, but it is also considered to be a reliable benchmark for the assessment of load intensity. **Objective:** The objective was to analyse the course of load intensity in the most exposed players during a second-league handball match in relation to the game positions.The heart rate of nine players (4 backs, 3 wings and 2 pivots) during individual matches was monitored using Polar Team². **Results:** The study results indicate statistically significant lower values in load intensity of players during the second half-time. The highest mean value of HR_{max} in all matches was determined in the backs: 83.0±6.1 % HR_{max}. These players also showed the highest decrease in load intensity (1st half-time 84.3±6.3 % HR_{max} ; 2nd half-time 81.1±5.6 % HR_{max}). In terms of practical significance ("effect size"), the difference can be considered medium-significant (Cohen's d = 0.52). The backs are often in contact with the ball, and they are the most involved in both defence and offence. The wings are mostly in static positions, and they had the lowest mean values: 80.3±9.7 % HR_{max}. **Conclusion:** Based on the results, we recommend including suitable game exercises in training of the same age and performance category with a similar intensity. The differences in the load intensity of female players are namely caused by the different game positions, the game system and the related.
Key Words: Sports game, heart rate, load intensity, heart rate monitor.

Introduction

Handball is a sports game that has spread all over the world and it is currently played by more than 19 million players (Saavedra, 2018). It is especially popular in European countries, such as Germany, France and Spain, and it is also a popular sports game to watch. As most team games, the handball game has recently accelerated. This applies both to the movement of players and to solving game situations (Vala et al., 2020). The ongoing changes are also affected by the continuous development in the tactics, related to the improved work of trainers and implementation teams that have been expanded with specialists in the individual fields of the training process. Specialists in scouting, statistics, fitness or nutrition have become an integral part of implementation teams, not only at the highest levels (Lorenzo et al., 2010; O'Donoghue, 2014; O'Donoghue & Holmes, 2014; Iacono et al., 2016; Wagner et al., 2016; Maulana et al., 2019).

Handball is an invasive and highly dynamic team sport, with typical random replacement of players who often have specific roles (defence and offence) within the individual short time intervals of the game. Low-intensity activities prevail during the match (e.g., walking and static positions such as standing reach up to 70 % of time), as stated by Karcher & Buchheit (2014). Despite that, handball can be considered an intensive activity, namely for the high number of repeated actions performed with sub-maximal or maximal intensity for a considerable part of the game. In relation to the game position, game tasks and selected tactics of the team, the players perform specific, high-intensity short-term game activities, such as sprint, jumping, changes in direction, personal encounters, turning, pushing, blocking and throwing (Milanese et al., 2012). In terms of physiology, it is an interval and interrupted type of physical activity (Granados et al., 2007).

Problem

Monitoring the current modern trends in sports game training and deducing the right conclusions in this relation has become a necessity. If we want to bring up players for this "modern" handball and be successful trainers, we must respond to such changes appropriately. Using "small side games" and other methodological-organisational forms seems essential in terms of long-term development in the game performance and influencing the conception of individual teams' preparations (Iacono et al., 2016). The relation between the players' load during matches and during the training process, i.e., training itself, is a critical issue in sports game training, which also includes handball (Puente et al., 2017; Vala et al., 2020).

Corresponding Author: ROMAN VALA, E-mail: roman.vala@vsb.cz

According to some authors (such as Douglas et al., 2019), we distinguish between external load, related to the physical activity, and internal load, which can be understood as a response of the organism to such activity. The presented work focuses on the internal load, which can be expressed by several characteristics. The heart rate (HR) is one of the easily available physiological indicators. The considerable number of original and reviewed articles on HR monitoring published in recent decades documents the high interest in exercise and sport science and indicates that it is one of the most frequently used parameters today (Mathew & Delextrat 2009; Montgomery, Pyne, & Minahan, 2010; Cuberek et al., 2017). Most of the previously mentioned authors as well as others (Benson & Connolly, 2011; Essner et al., 2013) agree that HR measurement can be considered a reliable quantity for the assessment of load intensity.

At the same time, the demands on the players' fitness increase, which also increases the importance of fitness indicators in the player evaluation. Recent studies (Buchheit, 2015; Sannicandro, Cofano, & Rosa, 2016; Gantois et al., 2017; Vanrenterghem et al., 2017; Thorpe et al., 2017; Schneider et al., 2018; Impellizzeri, Marcora, & Coutts, 2019; Shynkaruk et al., 2020; Andrianova et al., 2021) mostly react to the changes that have occurred in the load of sports game players. Considering the continuous development in the gear of players as well as the improved work of trainers and implementation teams, it is possible to expect more studies in the field of sports training and load intensity of sports game players in the future.

We believe that the analysis of the load intensity of the individual female players during championship matches we performed is a particularly important foundation for the work of the team trainer. The information obtained can be considered to be fundamental material for the subsequent preparation of a training plan, supervision and control of the training process and for the selection of suitable game exercises in the training (Vala, Valová, & Pacut, 2019).

Aim

The aim of the work was to compare the load intensity of second-league handball players during a championship match in relation to the game positions.

Methodology

Research Group

The research group where HR was monitored during the match included nine most exposed players in a second-league women's team (Table 1). The average age of the monitored players was 21.9±2.8 years, with an average height of 173.2±6.3 cm and the average body weight of the group was 64.2±4.3 kg. The tested group included four players at the back position, three at the wing position and 2 pivots.

Table 1 Basic Descriptive Group Statistics and Mean HR Values of Players in Matches (Expressed in HR Values)

Position and No	Age	Weight (kg)	Height (cm)	HR_{max}: Mean±SD (beats/min)
Wing 1	21	73	185	171.4±23.6
Wing 2	25	70	168	167.6±21.6
Wing 3	19	58	163	172.6±13.6
Back 4	24	64	176	173.4±13.5
Back 5	19	67	180	174.9±12.6
Back 6	18	60	170	179.5±10.4
Back 7	24	64	176	180.1±11.2
Pivot 8	26	66	171	185.9±20.3
Pivot 9	21	65	170	174.7±12.5
MEAN±SD	**21.9±2.8**	**64.2±4.3**	**173.2±6.3**	**175.6±15.5**

Note: *HR_{max} – mean is mean of maximal heart rate during championship matches (expressed in HR values) ± SD – Standard Deviation*

Methods

At the beginning of the season, the maximum heart rate of all team players was determined during load tests in laboratory conditions. The heart rate was continuously monitored using the Polar sporttester during the test. To diagnose the heart rate level in the players during the individual matches, we used the Polar Team² system (Polar Electro, Oy, Finland). In total, three domestic championship matches in the second highest competition of women's handball were analysed. The most exposed players were monitored in each match; provided that they played for at least 25 minutes and were also involved in both half-times.

Statistical Data Processing

To evaluate the obtained measurement data, we used Polar Precision Performance™ SW. The calculations of the mean HR values of players only included values of the individual second intervals when the players were actively involved in the game and the live time was running at the same time (Abdelkrim, El Fazaa, & El Ati, 2007; Vala, Valová, & Pacut, 2019). The IBM SPSS Statistics 23.0 program was used for the statistical processing of the obtained data. Statistical decision-making took place at 5% level of significance. Data normality as a presumption for the use of parametric forms of tests was rejected (Shapiro –Wilk test, p-value <0.05), therefore, non-parametric forms of tests were used for the evaluation of statistical significance. The obtained results were also assessed in terms of practical significance using the Effect of Size by Cohen (1988), who recommends the values of *Cohen's d* for the effect of size (0.2 = low effect; 0.5 = medium effect; 0.8 = high effect. The Bland & Altman plot (1986), created with the 'R' program, was also used to graphically evaluate the differences found in the load intensity of players between half-times.

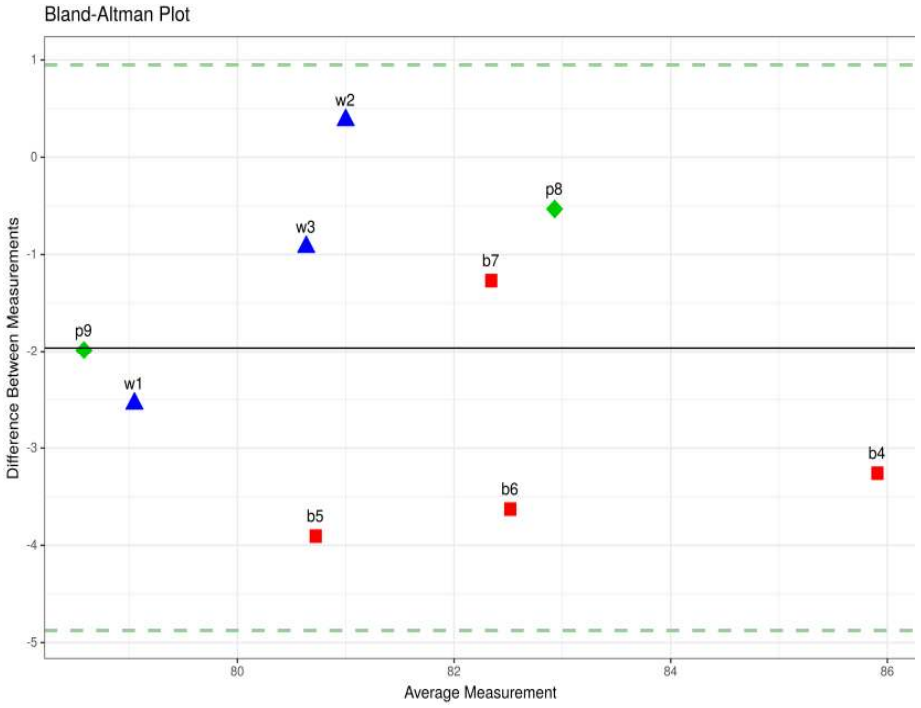
Results and Discussion

The mean load values at the level of 175.6±15.5 beats per minute (Table 1) were analysed in all the monitored players, regardless of their positions. When evaluating the load intensity of athletes, it is necessary to consider the different individual values in the maximal HR of the individual players; therefore, the maximal HR values of all the players were determined in laboratory conditions before the season. Table 2 shows the analysed values of the players' load intensity in both half-times of the individual matches as percentage of their maximal HR.

Without distinguishing between the players' positions, the mean load values of all monitored players in selected matches were analysed at the level of 81.6±7.9 % HR_{max}. The presented differences in the players' load intensity in all positions during all the matches (i.e., during both half-times) were analysed as statistically significant. Table 2 also implies that the differences stated can only be considered practically significant in players in the back position (Cohen's *d =0.52).* The analysis of the load intensity of monitored players only expressed by the HR values showed that the highest HR values were determined in a pivot player (185.9±8.9 beats per minute). This 26-year-old player (Pivot No. 8) was the oldest monitored player in the team.

When comparing the load intensity of the monitored players by the game positions, the highest load intensity was indicated in the second-league players at the back position: 83.0±6.1 % HR_{max} (176.8±12.4 beats per minute), when compared with players at the wing position: 80.3±9.7 % HR_{max} (170.3±20.6 beats per minute) and the pivots: 81.0±8.0 % HR_{max} (180.7±18.0 beats per minute). During the match, there was a decrease in the load intensity of the monitored players by about 2 % HR_{max} on average. The previously mentioned average decrease is also influenced by the fact that there was a slight increase in the load intensity in one player at the wing position by 0.4 % HR_{max} (see Figure 1: Bland - Altman Plot and Table 2).

Figure 1 Graph of Players' Load Intensity Comparison during Match Expressed in Percentage of HR_{max} (%)



The results of the second-league players' load intensity we present are much lower than results from other sports games, such as ice-hockey (Vala et. al., 2020) or basketball (Abdelkrim, El Fazaa, & El Ati 2007). In ice-hockey, however, there are no parts of the game (except for power play or one man short) when players would perform static tasks within their game positions, typical for pivot and wing players. The backs are continuously actively involved in the game in both defence and offence, while the wings often passively wait in the corner of the field to take a suitable position. The wings generally score a goal in the match from quick counterattacks or when the defence moves towards the centre of the field to help the pivots and the backs. The publication by Manchado et al. (2021) also confirms the previously mentioned differences in load intensity and the distance ran by handball players at various positions. Our conclusions in terms of different load intensity levels in relation to the game position are fully in compliance with the results of publications in the area of most sports games. Authors Mathew & Delextrat (2009), Abbott, Brickley, & Smeeton (2018) and Puente et al. (2017) agree that one of the most crucial factors that considerably influences the load intensity of sports game players is the position that the individual players take. The stated load intensity values of handball players are comparable with the results of a study focusing on load intensity during small-sided games in handball (Gümüş & Gençoğlu, 2020). However, the authors monitored all the handball players, including the goalkeepers, where the load values were lower which influenced the total average of the team.

Table 2 Load Intensity of Female Handball Players during Match in Relation to the Game Position (Expressed as Percentage of HR_{max})

Position	Half	Mean±SD	Max. Percentage of HR_{Max} (%)	p-value	ES
Wings	1st Half	80.7±10.2	103.8	< 0.001	0.09
	2nd Half	79.8±9.0	97.6		
Backs	1st Half	84.3± 6.3	101.1	< 0.001	0.52
	2nd Half	81.1±5.6	95.9		
Pivots	1st Half	81.6± 7.9	97.3	< 0.001	0.17
	2nd Half	80.2± 8.0	95.9		
ALL	1st Half	82.4±8.9	103.8	< 0.001	0.16
	2nd Half	80.4±8,0	97.6		

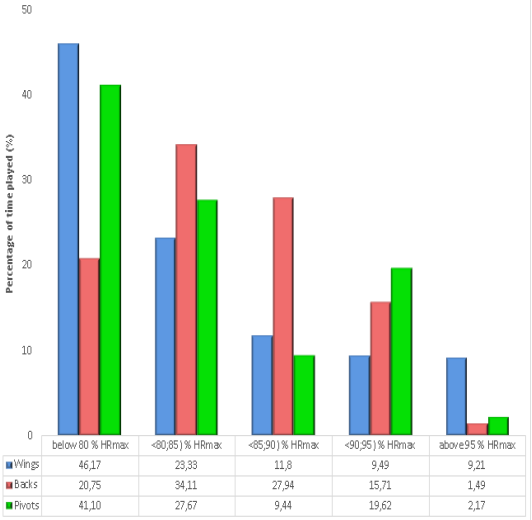
Note: *SD – Standard Deviation, Max. Percentage of HR_{max} maximal percentage of maximal heart rate during a championship matches, p-value (Wilcoxon test), ES – Effect Size (Cohen's d)*

As previously mentioned (Table 2), the highest load intensity values were determined in players at the back position: 84.3±6.3 % HR_{max} during the first half-times. Also, the highest decrease in load intensity during the match was determined in players at the same position (Picture 1 and Table 2). Table 2 also shows that even though the players' load intensity was at about 80% of the maximal HR, the maximal HR values determined in laboratory conditions were sometimes exceeded during a match. It might be more suitable to determine the HR_{max} values of players using field tests, such as the 'Yo-Yo Intermittent Recovery Test Level 1' (Abad et al., 2016; Bangsbo, Iaia, & Krustrup, 2008) which better 'simulate' typical load intensity of players in sports games where intermittent load is typical. Besides the mean HR values, it is also important to look at the distribution of load intensity during the match.

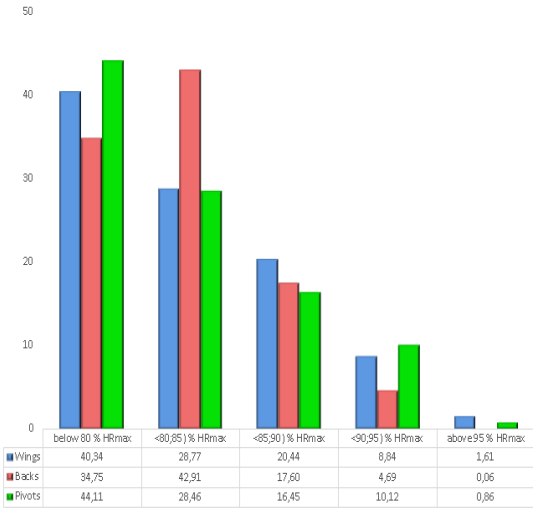
During the 1st half-time, the players were above 85% HR_{max} at 36.6 % of the played time; however, in the 2nd half-time, it was only 26.5 % of the played time above 85% HR_{max}. The graph in Picture No. 2 shows that the players at the back position were above 85% HR_{max} for 45.1 % of the played time, while the players at the remaining positions spend only 30.9 % of the played time above the value. However, in the course of the second half-time, the players at the back position were above 85% HR_{max} only for 22.4 % of the played time, while it was 29.2 % of the played time for the remaining players. Generally, the differences in the load intensity of sports game players are caused by the different game positions and the related player roles in the field.

The graphs also show that the players exceeded the level of 95% HR_{max} only minimally during the second half-time. The tasks and roles of the individual players at the various positions are mostly related to the applied game defence systems (zone, personal or combined), as well as offence systems (gradual or fast counterattack). The specific tasks of the individual players depend on the selected game systems. Moreover, the tasks often change during the match in relation to the development of the match and to the tactical instructions of the trainers. The players at the back positions must often move actively, both in defence and offence, because they are continuously active at the centre of the field where most of the actions of both teams take place. On the other hand, the players at the wing position fulfil several game activities of a 'positional and static' character (below 80% HR_{max}) or high-intensity activities, such as sprint – in particular, engagement in a fast counterattack (above 95% HR_{max}).

Figure 2 Graph of Distribution of Load Intensity of Players at Individual Game Positions in the Individual Zones Expressed in Percentage of HR_{max} (%), 1st half-time (a), 2nd half-time (b)



(a)



(b)

We need to mention that this is a second-league competition and none of the players can be considered a professional athlete with adequate conditions in the training process. An important factor affecting the HR values can thus include some limiting factors in the fitness of the players that do not have adequate training conditions in the club; they are often students or have regular jobs. The load intensity of elite female handball players is around 90% of their HR_{max} (Bělka et al., 2016). Another factor influencing load intensity can be the result of the individual matches. When the matches are even, the best players in both teams have to play with maximum commitment against the best players of the rival team for as long as possible. On the contrary, when the result of the match is obvious from early on, the load intensity may gradually decrease due to more frequent player replacements. In our case, data from three matches were used (one winning with a large goal difference; one highly even match, in the end won by 2 goals, and one lost match).

Monitoring load intensity in sports games with typical interval load is generally quite a problematic matter. There are more precise load indicators, such as oxygen consumption (VO_2); however, monitoring the HR is a practical and globally applicable method (Achten & Jeukendrup, 2003; Aoki et al., 2017). For more detailed and closer specification of the female players' load in the match, we would need to expand the study with heart rate monitoring in a larger group (more teams and players in the highest league), to monitor load in several matches under the same conditions. Also, it would be suitable to analyse load intensity in relation to the number of minutes played or monitoring the HR of players during the individual phases of the match, i.e., only the game intervals when the players engage in the offensive or defensive phase of the match.

Strengths and limitations

The results of the study are limited by various factors. These are mainly the specific roles of individual players within the same positions, the number of matches and their course, the time played in individual parts of the match, or the quality of the rival.

Conclusion

The results we received from the analysis of the female players' load intensity during several championship matches in handball should provide trainers with the basic load parameters at the particular performance level. Trainers should also consider those parameters when creating a training plan and also during the training process. The objective of the work was to analyse the course of load intensity of female handball players during a match in relation to their positions (wing, pivot and back). The highest determined mean value of HR_{max} during a match was analysed in the players at the back position: 83.0±6.1 % HR_{max}. These players are continuously on the move in both defensive and offensive phase, forming the game of the entire team. On the other hand, the lowest values were determined in players at the wing position, who fulfil more static tasks. In this case, the mean value of load intensity was analysed at 80.3±9.7 % of the maximum HR determined during the load test. Random selection situations are not usually used in the sports practice; therefore the load intensity results were also assessed in terms of practical significance ('effect size'). In terms of practical significance, the differences we found in the load intensity of all players during the match are assessed as insignificant (Cohen's $d < 0.16$). The results we obtained in the presented study on the load intensity of female second-league handball players during championship matches were used for the preparation of a training plan. They were also considered when selecting appropriate methodological-organisational forms and exercises in the training process of the team.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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