Determining the Degree of Load on the Body by Monitoring the Heart Rate in Ball Hockey in Men's Extra-League Matches

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ABSTRACT
Introduction: Ball hockey is a young, progressively developing sport that lacks research into players' loads in competitive matches. As far as we know, our work is the first.
Aim of Study: The work aims to solve the problem of determining the degree of load during a ball hockey match by monitoring and analyzing heart rate in selected matches of the extra league of ball hockey.
Material and Methods: The sample included ten ball hockey players (age 25 ± 5.21 years, height 184.2 ± 6.8 cm, weight 83.8 ± 11.48 kg) from three extra-league clubs in the positions of forwards (8) and defenders (2). The sample was monitored in six extra-league matches of the basic part of the seasons 2019-2020 and 2020-2021. Determination of the maximum heart rate (SF_{max}) was performed by the protocol of a modified Conconi test (Hnízdil, 2006) performed on an HP Cosmos Venus running ergometer (HP Cosmos Sports and Medical, Germany), which the test subjects completed in wrestling equipment without a ball hockey stick. According to Ben Abdelkrim et al. (2010), individual intensity zones were determined based on SF_{max} results. Heart rate measurement (SF) was performed by Polar Team 2 (Polar O.Y., Kempele, Finland), which records and stores SF in beats.min-1 for five seconds. The documentation of the matches was done with a Sony HDR-XR155E camcorder; the chronometer was made using a Secco stopwatch and a stopwatch on a mobile device. Video played in VLC player (Free Software Foundation, Inc., Boston, USA), SF evaluated in Polar Precision Performance 4.03.040 (Polar, OY, Kempele, Finland), and basic data processing was performed in Excel (Microsoft Corporation, California, USA).
Results: The ball hockey player moves on average in the extra league match 3.4% of the time in the zone above 95% SF_{max}, 22.8% of the time in the zone 85-95% SF_{max}, 25.4% of the time in the zone 75-84.99% SF_{max} and 48, 4% of the time in the zone below 75% SF_{max}. When changing to rest on the inverter, its load is in the ratio of 1: 2.9.
Conclusion: Our work is based on empirical findings brought by specific procedures for improving the training process. The limit of the work is the relatively low number of monitored matches and the low number of defenders. The work can be followed by detecting the load by more invasive methods ($VO2_{max}$, lactate), by detecting the

external load or by detecting the activity of the muscles in the load using EMG, or by searching for relationships between individual phenomena.
Keywords: Physiological load, Ball Hockey, Heartrate

SOUHRN

Úvod: Hokejbal je mladý progresivně se rozvíjející sport, kterému chybí výzkumná šetření odhalující
zatížení, které podstupují hráči v soutěžních zápasech. Pokud je nám známo, je naše práce v tomto směru
první.
Cíl: Cílem práce je přispět k řešení problematiky stanovení míry zatížení v průběhu hokejbalového
utkání, prostřednictvím monitoringu a analýzy srdeční frekvence u vybraných utkáních extraligy
hokejbalu.
Metody: Výběrový soubor zahrnoval 10 hráčů hokejbalu (věk 25 ± 5,21 let, výška 184,2 ± 6,8 cm,
váha 83,8 ± 11,48 kg) ze tří extraligových klubů na pozicích útočníci (8) a obránci (2). Výběrový soubor byl sledován v šesti extraligových zápasech základní části sezón 2019-2020 a 2020-2021. Před provedením výzkumného šetření byly získány informované souhlasy testovaných osob (dále jen TO), souhlasy hlavních trenérů dotčených klubů a souhlas Českomoravského svazu hokejbalu (dále jen ČMSHb) k provedení výzkumu. Stanovení maximální SF (dale jen SF_{max}) provedeno v laboratoři zátěžové diagnostiky Univerzity Jana Evangelisty Purkyně v Ústí nad Labem a to prostřednictvím modifikovaného Conconiho testu (Hnízdil, 2006). Individuální intenzivní pásma byla stanovena podle Ben Abdelkrim et al. (2010) na základě výsledků SF_{max}. Pro měření srdeční frekvence (dále jen SF) byl využit systém Polar Team 2 (Polar O.Y., Kempele, Finsko), který zaznamenává a ukládá SF v tepech.min^{-1} po pěti sekundách. Zadokumentování zápasů provedeno videokamerou Sony HDR-XR155E, chronometráž provedena pomocí stopek zn. Secco a stopek na mobilním zařízení. Videozáznam přehrán v programu VLC player (Free Software Foundation, Inc., Boston, USA), SF vyhodnocena v programu Polar Precision Perfomance 4.03.040 (Polar, O.Y., Kempele, Finsko) a základní statistické zpracování dat bylo provedeno v programu Excel (Microsoft Corporation, California, USA).
Výsledky: Hráč hokejbalu se průměrně pohybuje v zápase extraligy 3,4 % času v zóně nad 95 % SF_{max}, 22,8 % času v zóně 85 – 95 % SF_{max}, 25,4 % času v zóně 75 – 84,99 % SF_{max} a 48,4 % času v zóně pod 75 % SF_{max}. Jeho zatížení při střídání k odpočinku na střídačce je v poměru 1:2,9.
Závěr: Naše práce se opírá o empirická zjištění na jejichž základě přináší konkrétní postupy jak zkvalitnit tréninkový proces. Limitem práce je relativně nízký počet sledovaných utkání a nízký počet obránců. Na práci lze navázat zjišťování zatížení invazivnějšíma metodama (VO_{2max}, laktát), zjišťováním vnějšího zatížení nebo

odhalováním aktivity svalů v zátěži pomocí EMG a nebo hledáním vztahů mezi jednotlivými fenomény.
Klíčová slova: Fyziologické zatížení, Hokejbal, Srdeční frekvence.

INTRODUCTION

Team sports are a phenomenon of contemporary society. The best teams in the world watch millions of spectators. There is a relatively significant difference in the popularity and support of team sports, which is reflected in their development. Ball hockey is a relatively young sports game that is looking for its place in the limelight of world sports. It is based on ice hockey (Perič, Přerost, & Kadaně, 2006) and is classified as a collective, invasive, goal team sport (Lehnert et al., 2014). The specificity of ball hockey is the rule of the floating offensive zone defined according to the rules of the Czech-Moravian Ball Hockey Association (2018) as follows: "If the ball is introduced or passed behind the offensive blue line, "Floats" to red)" (p. 46). In the specialized literature (Perič et al., 2006; Pek 1998) the load in ball hockey is, in our opinion, insufficiently described in comparison with other intermittent team sports such as ice hockey (Bukač & Dovalil, 1990; Havlíčková, 1993; Stanula & Roczniok, 2014), floorball (Kysel, 2010), handball (Lehnert et al., 2014), basketball (Havlíčková, 1993; McInnes, Carlson, Jones, & McKenna, 1995; Lehnert et al., 2014) or futsal (Barbero - Alvarez, JC, Soto, Barbero-Alvarez, V., & Granda-Vera, 2008; Hůlka et al., 2014; Weisser, Bělka, Hůlka, Houdková, & Koruna, 2012). It cannot be otherwise because research investigations aimed at revealing the load in ball hockey are absent. Clarified phenomena from exercise physiology generally apply to ball hockey, and knowledge from ice hockey is adopted (Pek, 1998; Perič et al., 2006). Pek (1998) specifies the load in ball hockey as follows: "aerobic processes reach 80-90% of maximum values and SF reaches 87-92% of maximum" (p. 151). Hůlka et al. (2014) and Lehnert et al. (2014) state that the load in team sports can be monitored based on the parameters of the work performed (external load) and according to the organism's response to this load (internal load). The most suitable and one of the most available methods of internal load analysis is SF measurement (Süss, 2006).

SF is a designation for the rate of work of the heart muscle given in the number of contractions per unit time, most often beats.min-1 (Dong, 2016). The activity of the heart muscle is driven by electrical stimuli, which arise involuntarily in the pacemaker (sinus node) and are controlled by the autonomic nervous system (ANS). Increasing the excitation rate causes sympathetic ANS, and decreasing the rate of excitation causes parasympathetic ANS (Merkunová & Orel, 2008). SF is affected by several factors that affect its values. These factors include age (Hnízdil, 2011; Nes, Janszky, Wisløff, Støylen, & Karlsen, 2012; Zahradník & Korvas, 2012), gender (Benson & Connoly, 2011), heart size and athletic performance (Novotný, 2017; Žiška , Olasz & Krčmár, 2016), psychoemotional load (Havlíčková et al., 1994; Hnízdil, 2011; Merkunová & Orel, 2008), drinking regime and nutrition (Hnízdil, 2006, 2011; Hnízdil et al., 2012; Safarian, Charrière , Maufrais, & Montani, 2019), pharmaceuticals (Hnízdil, 2006, 2011; Proud 2006), medical condition (Filarecka & Biernacki, 2018),

body position (Abad et al., 2017; Hnízdil, 2011; Jeukendrup & Van Diemen , 1998; Rendos, Musto & Signorile, 2015; Vujkov, Casals, Krneta, & Drid, 2016; Watanabe, Reece & Polus, 2007), ambient temperature (Malcolm, Cooper, Folland, Tyler, & Sunderland, 2018; Pilch et al. ., 2019), altitude (Bhattarai et al., 2018; Jereb & Burnik, 2010) and aquatic environment (Alberton & Kruel, 2009; Thiel & Sýkora, 2016). These factors are not the only methodological problem in measuring SF. Load intermittency comes into play, causing a delay of up to 30 seconds in the current SF (Lehnert et al., 2014).

In order to determine the load according to SF, it is necessary to know SF_{max} (Süss, 2006). This value can be accurately measured using standardized stress tests performed in a laboratory environment on certified facilities (Heller, 2018; Hnízdil, 2011). The so-called intensive zones were developed for the needs of team sports (Table 1). They are most often built into different SF_{max} percentage zones (Ben Abdelkrim et al., 2010; Da Silva et al., 2018; Hůlka et al., 2014; Lehnert et al., 2014; McInnes et al., 1995; Tessitore et al., 1995; ., 2005; Vencúrik, Nykodým, & Vacenovský, 2016), less often to SF values in the $VO2_{max}$ percentage zones (Lucia, Hoyos, Carvajal, & Chicharro, 1999; Santalla, Earnest, Rodriguez-Marroyo, & Lucia, 2012) and sometimes you can also find the division of the zones into individual beats (Agraj, 2005; Bílek, 1983; Capranica, Tessitore, Guidetti, & Figura, 2001). Some studies manifest results by average SF per match (Ali & Farrelly).

Table 1. Heart Rate Zones Types

Form[a]	Marker	Intensive Zones Range											
1	SF_{max}	< 85 %						> 85 %					
2	SF_{max}	< 65 %			65 – 85%			> 85 %					
3	SF_{max}	< 85 %			85 – 95 %			> 95 %					
4	SF_{max}	< 75 %			75 – 84 %			85 – 95 %			> 95 %		
5	SF_{max}	50 – 60 %			60 – 70 %			70 – 80 %			80 – 90 %		> 90 %
6	SF_{max}	< 70 %			71 – 85 %			86 – 90 %			91 – 95 %		> 95 %
7	SF_{max}	< 75 %		75 ≤ 80 %			80 ≤ 85 %			85 ≤ 90 %			90 ≤ 95 %	≥ 95 %
8	VO_{2max}	SF < 70 %			SF 70 – 90 %			SF > 90 %					
9	VO_{2max}	SF < VT_1			SF VT_1 – VT_2			SF > VT_2					
10	$t.m^{-1}$	< 150						> 150					
11	$t.m^{-1}$	< 120		121 – 140			141 – 160			161 – 180			181 – 200	> 201
12	$t.m^{-1}$	<110	110	120	130	140	150	160	170	180	190	200	210	>210

SF = heart rate; SF_{max} = maximal heart rate; VO_{2max} = maximal oxygen consumption; $t.m^{-1}$ = beats per minute; VT_1 = aerobic ventilation threshold; VT_2 = anaerobic ventilation threshold.
[a] Form 1 according to Tessitore et al. (2005), 2 according to Lehnert et al. (2014), 3 according to Vencúrik et al. (2016), 4 according to Ben Abdelkrim et al. (2010), 5 according to Hůlka et al. (2014), 6 according to Da Silva et al. (2018), 7 according to McInnes et al. (1995), 8 according to Santalla et al. (2012), 9 according to Lucia et al. (1999), 10 according to Bílek (1983), 11 according to Agraj (2005), 12 according to Capranica et al. (2001).

The values obtained by monitoring SF serve as an estimate of the load and do not indicate the type of load (locomotion and involvement of the main muscle groups). In addition, load intermittency overestimates energy expenditure by 5 to 20% (Hůlka et

al., 2014). Ventilation appears to be a better indicator for estimating energy expenditure (Gastinger, Sorel, Nicolas, Gratas-Delamarche, & Prioux, 2010), which is not feasible for application to competitive matches. Nevertheless, even though SF monitoring is burdened with methodological problems, it is the most widely used method of internal load analysis in a match (Hůlka et al., 2014).

MATERIAL AND METHODS

Participants

The group included ten players (age 25 ± 5.21 years, height 184.2 ± 6.8 cm, weight 83.8 ± 11.48 kg) from three clubs in the positions of offenders (8) and defenders (2). We monitored the tested persons (TP) in six competitive ball hockey matches of the extra senior league of the Czech Republic in the seasons 2019-2020 and 2020-2021. To maintain anonymity, abbreviations TP1-10 were created for TP. The group was selected by a combination of intentional selection and selection methods based on voluntariness in self-selection (Reichel, 2009). Prior to the commencement of the research survey, the tested persons were informed of the risks associated with the conduct of the research, and they signed informed consent. Furthermore, because they are registered with the parent club, consent was obtained for their participation with the head coaches of the clubs concerned.

Research design

SF load zones were determined for load assessment according to Ben Abdelkrim et al. (2010). The baseline value for the calculation of intensive zones was SF_{max} determined by laboratory testing, and where the SFmax value exceeded the value from the laboratory test, the newly obtained SFmax was used. All SF measurements at the test persons (TP) were performed with the Polar Team 2 system (Polar O.Y., Kempele, Finland), which stores SF values in beats.min-1 in the chest receiver after five seconds.

Laboratory testing took place in the functional diagnostics laboratory of the Department of Physical Education and Sport, Jan Evangelista Purkyně University in Ústí nad Labem. Prior to laboratory testing, TPs were asked to refrain from alcohol, drug use, increased physical activity 24 hours prior to testing, and stop eating 2 hours before testing. According to our information, each TP has encountered training in the same type of equipment in the past. One of the standardized test requirements is the specificity, which we tried to increase by dressing the TP in complete ball hockey equipment without a ball hockey stick. Some players play shin guards, and some do not. Their use in the test depended on their wearing during matches. Thus, the testing took place in sportswear, which was increased by a helmet, gloves, and, in some players, razors.

TPs started a warm-up, which took place on a running ergometer. The warm-up lasted 8 minutes, when it was divided into two consecutive speed sections, with the first section being 4 minutes long with a speed of 9 km.h-1 and the second 4 minutes long with a speed of 11 km.h-1. Subsequently, the muscle parts were warmed up and switched to a test motorized running ergometer HP Cosmos Venus (HP Cosmos Sports

and Medical, Germany), on which a modified Conconi protocol with a fixed distance was set (Hnízdil, 2006). The inclination of the ergometer belt was set to 1%, which compensated for the resistance of the environment. The starting speed is set at 11 km.h-1, when after every 150 meters, the belt speed increases by 0.5 km.h-1. The test took place until the subjective exhaustion of the TP.

The match measurement took place in the official matches of the ball hockey extra league, and the approval of the ČMSHb was obtained for the transparency of the research. Before each match, the leading referees were informed about the ongoing research. They were also told that players with unique markings on their helmets are participating in the research (consent to the placement of these markings was obtained from the ČMSHb technical committee).

Because the Polar Team 2 system cannot record the split times entered by the distance evaluator, a basic timeline was created, measured with a Secco stopwatch, and checked the accuracy with a stopwatch on a mobile phone. For the future synchronization of measuring and monitoring devices, a record sheet was created, in which the split times of the monitored phenomena were recorded (activation of each chest receiver, beginning, and end of each third). The measurement took place in such a way that a meeting with the TP took place in the range of one to an hour and a half before the match (a time chosen so that the TP would not interfere with the warm-up and focus on the match), during which the chest straps were fastened. Subsequently, the optimal place was found to place a recording device with a good view of the stadium's inverters. Monitored matches were recorded on a Sony HDR-XR155E camcorder with a tripod and its memory, which was turned on before the start of each third and turned off after the end of each third to save battery power. After the match, a meeting took place with the TP, at which the monitoring was completed (switching off the receiver and stopwatch).

Data processing

Data from laboratory testing and monitored matches were transferred to a laptop, from which SFmax values and SF values from matches were obtained. The videos were played in the VLC player program (Free Software Foundation, Inc., Boston, USA), in which the start and end times of the periods and the beginning (entry to the course, standard) were searched for and recorded in Excel (Microsoft Corporation, California, USA), interruption and end of rotation (entry to the substitute, referee's whistle). In Excel, the basic timeline was used to convert the times of these phenomena to the times recorded in the chest receivers. After synchronization, these phenomena, together with the intense zones, were entered into the Polar Precision Performance 4.03.040 program (Polar, O.Y., Kempele, Finland), in which the results of the time spent in each zone for each player for each match were evaluated. Basic data processing is performed in Excel. We interpret the results of intensive zones as a percentage of time spent in individual zones. We interpret other results as mean values (M) ± standard deviation (SD).

In order to interpret the results, it was necessary to establish some deadlines on which the results are based. The insertion of the introductory bully defines the beginning of the period. The end of the period is defined by the referee's whistle, after which the break occurs. The start of substitution is defined as when the ball is thrown or running onto the court during a free substitution. The end of the substitution is defined by running out of the court in a free substitution or by the referee's whistle, after which the player was replaced. The net time of the game is limited to the beginning and end of the substitution and does not include the time spent between the referee's whistle and the subsequent throw-in. The time in the match is limited to the beginning and end of the periods, so it does not include the time of breaks between the thirds. In the study, we monitored selected phenomena that are defined by the value of SF at individual moments of the beginning of periods (insertion of the introductory bully), beginning and end of the rotation, culmination of SF (moment of the highest SF value recorded from the beginning of rotation to beginning of next rotation). The average rest period is defined by the elapsed time from the end of the run to the beginning of the run. Finally, the average length of the rotation is limited by the beginning and end of the rotation.

RESULTS

The work aimed to contribute to the solution of determining the degree of load during a ball hockey match by monitoring and analyzing heart rate in selected matches of the ball hockey extra league.

Table 2 interprets individual intensive zone calculations from laboratory testing results and increased SF values from matches.

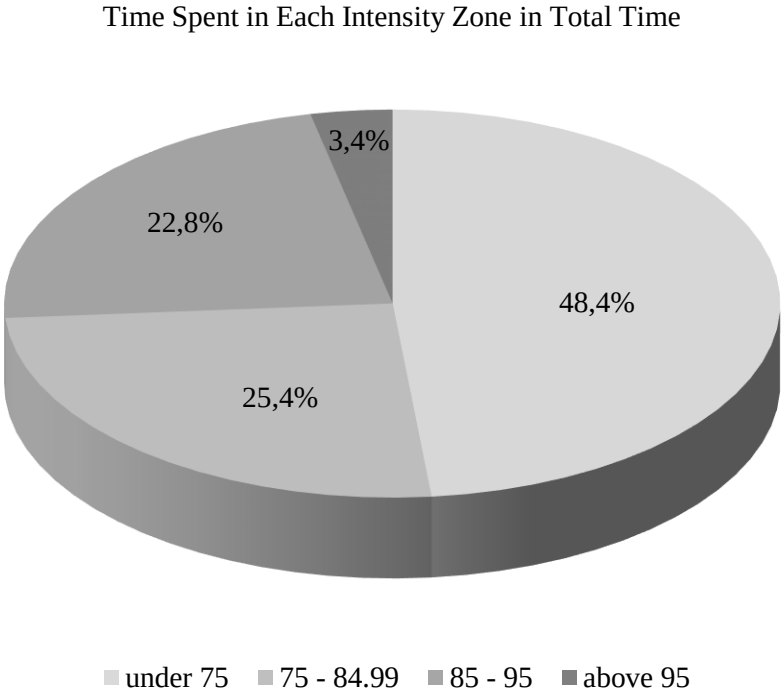
Table 2. Range of Individual Heart Rate Values in Intensive Zones

TP	Intensity Zones in % SF_{max}					
	< 75	75 – 84.99	85 – 95	> 95	$SF_{max}1$	$SF_{max}2$
TP1	< 139.5	139.5 – 158.0	158.1 – 176.7	> 176.7	186	
TP2[a]	< 151.5	151.5 – 171.6	171.7 – 191.9	> 191.9	202	
TP3	< 143.3	143.3 – 162.3	162.4 – 181.5	> 181.5	191	
TP4	< 145.0	145.0 – 164.8	164.9 – 184.3	> 184.3	194	
TP5	< 138.0	138.0 – 156.3	156.4 – 174.8	> 174.8	184	
TP6	< 156.0	156.0 – 176.7	176.8 – 197.6	> 197.6	207	208
TP7	< 140.3	140.3 – 158.9	159.0 – 177.7	> 177.7	184	187
TP8	< 146.3	146.3 – 165.8	165.8 – 185.3	> 185.3	191	195
TP9[a]	< 152.3	152.3 – 172.5	172.6 – 192.9	> 192.9	203	
TP10	< 140.3	140.3 – 158.9	159.0 – 177.7	> 177.7	187	

Values are given in beats.min^{-1}; SF_{max} = maximal heart rate; $SF_{max}1$ = results of laboratory testing, $SF_{max}2$ = maximum from the match.

[a] *The player is the defense player.*

In team sports, the results of intensive SF zones from the entire match are interpreted, including net playing time, interruptions in the game, and rest on the substitute. In Graph 1, we present the results of our survey, which shows that the ball hockey player moves on average in the extra league match 3.4% of the time in the zone above 95% SF_{max}, 22.8% of the time in the zone 85 - 95% SF_{max}, 25.4 % of the time in zone 75 - 84.99% SF_{max} and 48.4% of the time in the zone below 75% SF_{max}. The average value of SF in the match is at the level of 76.41% SF_{max}, which includes measurements from the beginning to the end of thirds.



Graph 1. Intensive zones of all players in all matches expressed as a percentage of time

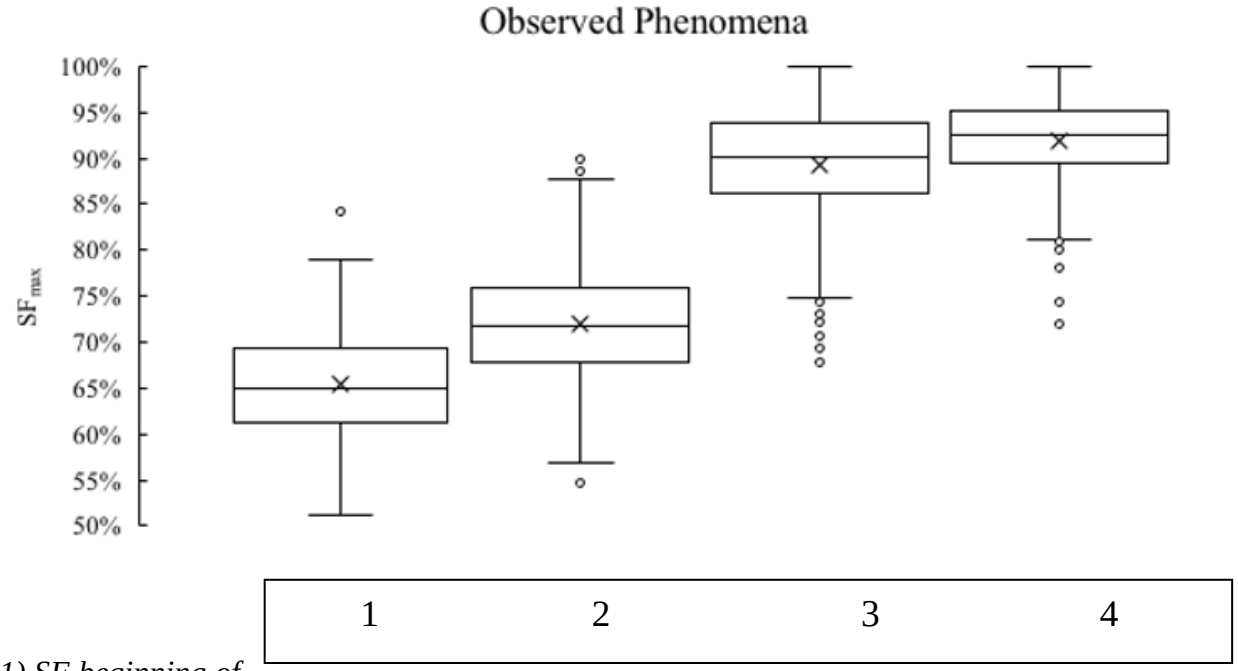
Some studies deal with a more detailed analysis of SF and evaluate the intense zones of SF in the net time of the game, i.e., without taking into account interruptions in the game and rest. In Table 3, we present an evaluation of the net time of the game, from which it is evident that the players are undergoing a somewhat more demanding load than the result of the interpretation of the results of the entire match. To evaluate the net time of the game, we found it interesting to divide the results into offenders and defenders in various game situations such as balanced and unbalanced situations.

Table 3. Time Spent in the Intense Zones of SF Net Game Time

Game Situation	Group	< 75 % SF_{max}	75-84.99 % SF_{max}	85-95 % SF_{max}	> 95 % SF_{max}
Five Against Five	Everyone	21.8	33.5	39.4	5.3
	Offenders	18.5	32.2	42.6	6.7
	Defenders	33.8	38.3	27.6	0.3
Power Play	Everyone	12.1	35.8	43.8	8.3
	Offenders	9.5	32.9	48.0	9.6
	Defenders	28.6	53.8	17.6	0.0
Short-Handed Play	Everyone	21.4	33.7	42.4	2.5
	Offenders	15.3	31.6	49.9	3.2
	Defenders	46.1	42.1	11.8	0.0

Values are given as a percentage of the time spent in the given zone. Own source.

As part of the revelation of some relationships, we were interested in the value of SF in selected phenomena (Graph 2). SF at the beginning of the rotation is at the level of 71.88 ± 6.45% SF_{max}, SF at the end of the rotation is 89.33 ± 5.93% SF_{max}, and the culmination of SF reaches an average of 91.89 ± 4.52% SF_{max}. The culmination of SF in our research occurs after the end of the rotation in an average of 11 ± 6 seconds and increases by an average of 5.96 ± 6.37 beats.min-1. We measured the psychoemotional load at the beginning of the thirds at the moment when the initial bulge was thrown in, and the need for energy expenditure did not cause the increase in SF. The average SF value at the beginning of all periods for all players is 65.46 ± 5.90% SF_{max}. An interpersonal evaluation of the observed phenomena is provided in Table 4.



1) SF beginning of the period;2) SF beginning of the alternation;3) SF end of the alternation;4)SF culmination

Graph 2. SF_{max} Values for Observed Phenomena

Table 4. Interpersonal Values of SF in Selected Phenomena

Phenomena		TP1[a]	TP2	TP3	TP4	TP5	TP6	TP7	TP8	TP9[a]	TP10
SF at the Beginning of the Rotation	M	67.00	66.61	69.82	72.53	76.39	75.25	79.18	72.89	69.61	72.50
	SD	5.04	6.73	3.49	6.33	4.89	5.63	4.47	4.18	4.11	6.06
	Min	54.84	47.03	62.30	54.64	66.30	64.42	64.17	65.64	59.61	63.10
	Max	80.11	78.71	76.44	84.02	88.59	89.90	87.70	85.13	75.86	86.10
SF at the End of Rotation	M	84.83	89.50	88.21	89.15	90.43	94.22	93.85	89.68	87.45	86.87
	SD	5.76	6.07	5.27	5.33	6.46	3.41	3.96	5.84	4.05	5.39
	Min	67.74	69.31	70.68	72.16	75.00	83.64	78.61	73.85	79.80	71.12
	Max	94.62	97.52	95.29	96.91	97.83	100.00	99.47	97.95	94.09	94.12
SF Culmination	M	87.43	92.35	90.68	91.62	97.26	95.24	95.16	91.94	89.87	90.46
	SD	4.87	3.31	4.02	3.23	1.65	2.85	3.45	4.91	3.18	2.91
	Min	72.04	85.64	74.35	83.51	92.93	87.50	81.82	78.46	85.71	82.89
	Max	97.31	97.52	97.38	98.97	100.00	100.00	100.00	100.00	95.57	97.33
SF at the Beginning of the Period	M	60.16	63.09	67.95	65.35	70.47	69.15	71.48	66.58	60.34	65.24
	SD	5.15	5.76	4.07	5.98	12.69	2.52	4.27	3.23	3.81	2.77
	Min	51.08	57.43	62.30	57.73	59.24	64.42	64.14	61.54	53.69	62.57
	Max	68.28	74.26	74.87	78.87	84.24	71.15	75.94	70.77	64.53	70.05

Values are expressed as a percentage of the SF_{max} of a particular TP; TP = test person; M = arithmetic mean; SD = standard deviation; Min = minimum value of all values obtained; Max = value of all values obtained.

[a] *The player is the defense player.*

As part of the evaluation of the research survey, we came to interesting data that cannot be left out. From the analysis of the obtained data, we found that the player will play an average of 5.90 ± 1.10 substitutions per third and 17.70 ± 1.99 substitutions per match. Therefore, he will play an average of 14:39 ± 02:34 minutes of net time in the match. The average substitution of the player is 01:02 ± 00:37 minutes, of which the net time of the game is 00:50 ± 00:25 minutes. The average rest between rotations is 03:01 ± 01:42 minutes. During the research survey, 407 runs were evaluated, which helped determine the relationship between runs and rest relevant. The ratio of time to rest is 1: 2.9 and was calculated from the average length of rest (181 seconds) and the average length of change (62 seconds).

DISCUSSION

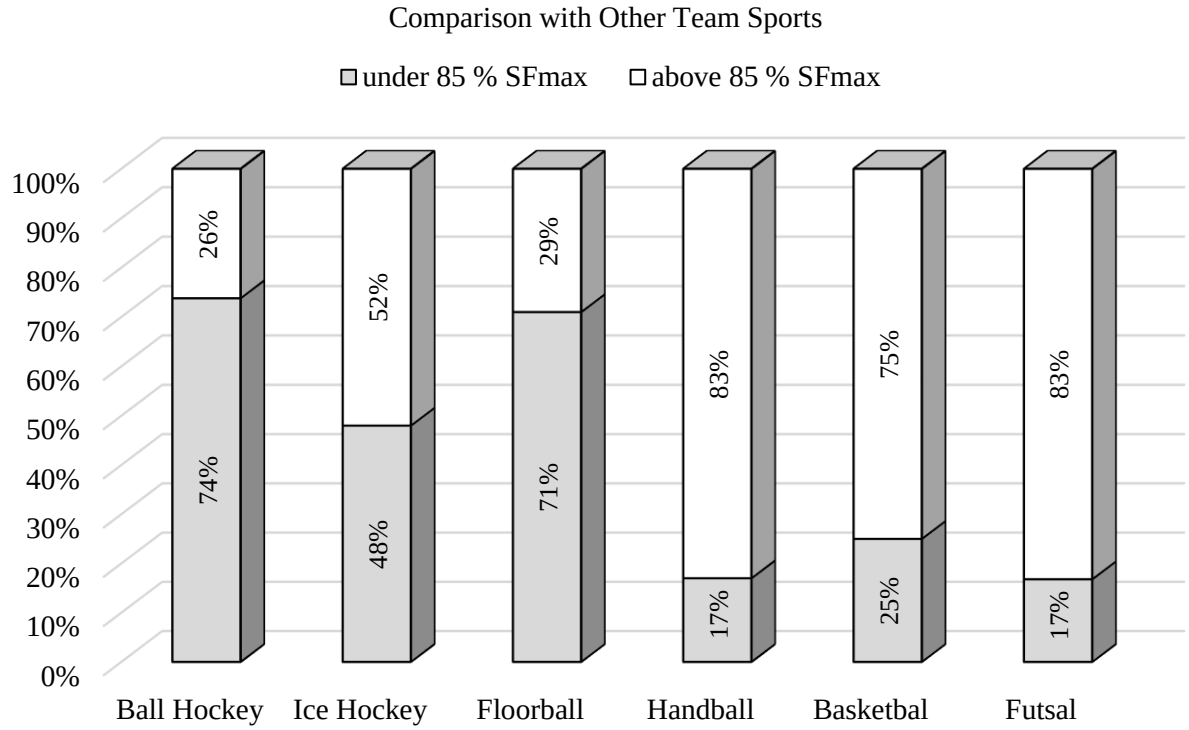
This study aimed to analyze the heart rate responses of extra-league ball hockey players in the matches of the basic part of the 2019/2020 and 2020/2021 seasons. Unfortunately, as far as we know, no study has addressed this issue yet.

When obtaining fundamental data, we used laboratory testing as a standardized method for determining SF_{max} values using a running ergometer. We know that the TP must master specific skills resulting from moving on the treadmill (Heller, 2018). During the research, it turned out that the laboratory values measured by us were not their maximum in all persons. Some TPs in the match exceeded the measured SF maximum observed in the laboratory. This can be justified by the high motivational effect on the player during the match (Petráš, 2018) or by an inappropriately chosen

test (Santos, Silva, Farinatti, & Monteiro, 2005). We think that this is the motivating factor that increased our SF_{max} values, mainly because no player had a plateau phase in laboratory testing (Heller, 2018; Nes et al., 2012).

We interpreted the results to summarize all the time spent in the match playing. Time spent in the third period is not included in the result. The results show an equilibrium game of five against five and all kinds of power play (5-4, 5-3, 4-3) and short-handed play (4-5, 3-5, 3-4). When interpreting the results, it is necessary to consider the fact that the players played against different opponents who professed different playing styles. It is also necessary to realize that the players had to follow their team strategy, the strategy of their line, and their position. Each of the players had different team tasks, and he was differently included in the game and different game situations. All these variables are signed on the final interpretation.

The interpretation of results in intensive zones has a severe limit. In Table 1, we have provided an overview of SF intensive zones, and we are convinced that there are several other possibilities for interpretation in the world. This diversity makes it impossible to compare individual team sports simply with each other. Perhaps the question is how the results should be interpreted. There is a variant of creating a methodological recommendation that team sports are evaluated primarily by individual percentages of SF_{max}, from which it would then be easy to calculate any ranges of intensive SF zones. This would leave the option of choosing the primary interpretation of the results and provide other authors with the possibility of comparison. We tried a similar comparison in Graph 3, where we identified the limit of 85% SF_{max} as the common denominator. It turns out that the most similar load for ball hockey players is for floorball players.



Graph 3. Comparison with Other Team Sports. Values are given as a percentage of the time spent in a particular SF zone.

The fact that significantly affects SF is the time spent on the field. The longer the player was under load, the closer he got to his maximum. The average substitution time is one minute, and the net game time spent in one substitution is about 50 seconds. However, in the match, it happened to us that the player was not at all on this average. It was either due to a short rotation or an extended rotation due to the impossibility of substitution. Differences in the number of substitutions for individual players per match are also included in the final result. The players from the third line are less deployed in particular formations, and thus their time between individual rotations is many times higher. Especially in moments when there is systematic exclusion, both on the opponent's side or the side of the monitored team. Such a player has undergone a maximum of four rotations per third, as opposed to the busier player, who regularly manages six or more rotations per one period. We watched the most prolonged delay between the two substitutions for the TP9 player with a length of 12:45 minutes.

Net game time is essential to clarify the specific load of individual players in specific game situations (balanced and non-balanced games). As expected, the time spent in the higher SF zones increased, as the evaluation did not include rest or interruption in the game. As part of the net game time evaluation, we evaluated the particularly net game time in a five-on-five game, a short-handed play, and a power play. In these situations, we have even shared the burden of attackers and defenders. In unbalanced situations, we no longer distinguish between short-handed play and the type of power play. We would need much more data for this, so we are not sure whether the results are sufficiently quantified, and therefore we must self-critically evaluate that better results would be achieved with more extensive measurements.

On the other hand, these data are instead a tertiary result in the whole spectrum of results. Interestingly, the power play was played from 20.8% of the net game time, and the short-handed play was played from 12.3%. The remaining 66.9% of the game time was five against five.

SF at the beginning of rotation is a theoretical indicator of an individual's ability to recover from exercise (Ostojic et al., 2010). After the rotation, the players were at the level of 72% SF_{max}, similar to the SF caused by emotional action at the beginning of the periods (65% SF_{max}). TP7, who was at less than 80% SF_{max} at the beginning of the rotation, has the highest values. It must be added that this player was the most involved in the game.

SF at the end of the rotation reaches significantly higher values, which can be said to be that players reach the level of less than 90% SF_{max}. We had a value of 100% SF_{max} once for the TP6 player within the results. This player has values of less than 95% SF_{max}. TP7 and TP5 are approaching this individual. The TP1 player (defender) is significantly low, reaching values just below 85% SF_{max}.

Some players reach the heart rate peak at 100% SF_{max} (four occurrences). However, the players reached an average of less than 92% SF_{max}. The lowest values were again recorded for the TP1 defender (87.43% SF_{max}). The exciting thing about the culmination of SF is that it occurs after the end of the rotation in most cases. We did

not observe this phenomenon in 32 cases (7.86% of all cases), which culminated during the rotation, and in 70 cases (17.20% of all cases), the culmination was at the end of the rotation.

Previously, the ČMSHb methodology took over the ratio of load to rest from the ice hockey results (Komárek, 2019, telephone interview). The ratio of 1: 5 was most often reported (Bukač & Dovalil, 1990). Today, the association's methodology does not specify load conditions (Komárek, 2020). Our study, evaluating 407 rotations, concluded that the ratio of the entire rotation to rest is 1: 2.9. We think this is the most appropriate indicator of the load-to-rest ratio, as it is limited by the player's entry and exit into the game process. This ratio is calculated with the inclusion of 00:00 minutes in the average rest (end of the third). Without this, the ratio in the results for each value will increase by 0.1, which we do not consider a distorting indicator. Regarding the ratio, it should be noted that we have calculated all the ratios in all rotations for our own needs, and as an interesting fact, we state the lowest ratio of 1: 0.3 and, conversely, the highest at 1: 66.9. These two extremes show how variable ball hockey is.

We did not include overtime data in the standard results. This happened twice; once we ran out of camera battery and therefore could not be evaluated. In the second case, one player played one substitution in overtime. Therefore, we will add that overtime is played three against three. One case of not recording one-third also did not get into the results because the receiver was released to the player during a personal duel in the first rotation of the second third. He corrected his commitment only during the break between the thirds, where he noticed this release.

One player experienced an unexplained extreme one-time decrease in SF during the research. We observed this decrease eight times, and therefore we do not take it as an artifact that distorts the results compared to the total number of recorded heartbeats.min^{-1}.

CONCLUSION

Ball hockey load manifested by heart rate is most to floorball load. Players move above the level of 85% SF_{max} in 26.2% of the time, of which 3.4% of the time in the zone above 95% SF_{max}. In the pure-play, players are above 85% SF_{max} in 44.7% of the time, of which 5.3% are in the zone above 95% SF_{max}. The psychoemotional load at the moment of the beginning of the third increases the SF to the level of 65.46% SF_{max}. At the start of the new substitution, SF players have 71.88% SF_{max}. At the end of the rotation, SFs have 89.33% SF_{max}. Load intermittency causes a delay in the SF peak, which occurs on average 11 seconds after the run and increases by an average of 5.96 bpm per minute to 91.89% SF_{max}.

The ball hockey substitution is played for an average of 62 seconds, of which the average playing time is an average of 50 seconds. This is followed by a rest of 3:01 minutes on average. The ratio between rotation and rest is 1: 2.9.

The research limit is the relatively small number of measured matches, which would help to better explain the load in various unbalanced situations, such as

overpowering and weakening. It would also be obvious to increase defenders' ratio to attackers and include goalkeepers in the monitoring.

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