



## THE INTENSITY AND ENERGY EXPENDITURE OF EXERTIONS, RESTITUTION SPEED, AND RATE OF PERCEIVED EXERTION AFTER TOURNAMENT MATCHES IN POLISH FUTSAL PLAYERS

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### ABSTRACT

**Purpose.** Futsal is a very dynamic indoor team sport. Like in soccer, futsal players perform a number of efforts of different intensity during a match. In each match there are a few return substitutions to allow players to have some rest. The aim of the study was to assess the intensity and energy expenditure of single efforts and the dynamics of restitution after the efforts during successive futsal matches.

**Methods.** The study consisted in measuring the players' ( $n = 11$ ) heart rate (HR) during four matches: A, B, C, D. The HR measurement started during a pre-match warm-up and ended 5 min after the match.

**Results.** The highest intensity of single efforts was noticed in match A. It equalled  $90.22 \pm 4.90\%$  HR<sub>max</sub> and it was the highest in comparison with other matches ( $p < 0.05$ ). The energy expenditure of efforts performed by players in the matches was  $395.11 \pm 118.70$  kcal. The mean energy expenditure of a single effort was  $16.33 \pm 5.36$  kcal/min. The highest energy expenditure was registered in match A, and it equalled  $17.31 \pm 4.71$  kcal/min during a single effort on the pitch after a return substitution.

**Conclusions.** The intensity was very high, much higher than that of players' efforts in 11-a-side soccer. It should be concluded that an appropriate reduction in the time players spend on the pitch during their successive efforts in one match and the consecutive tournament matches can result in reducing the decrease in the effort intensity.

**Key words:** futsal, intensity of efforts, energy expenditure, heart rate, restitution, RPE

### Introduction

The first official international futsal tournament was held in 1965 and the teams competed for the South American Cup. In 1971, the International Futsal Federation (FIFUSA, Federación Internacional de Fútbol de Salón) was founded. Its main goal was to standardize the rules of the game and to manage and control tournaments. Since 1988, international futsal tournaments have been held under the aegis of the International Federation of Association Football (FIFA, Fédération Internationale de Football Association). In 2002, the World Futsal Association (AMF, Asociación Mundial de Fútbol de Salón), independent of FIFA, was created.

Futsal is a variety of soccer. It is played indoors on a pitch of  $40 \times 20$  m. A futsal team can consist of 12 players. There are 5 players from both teams on the pitch

(1 goalkeeper + 4 field players). There are unlimited substitutions, players are also allowed to return onto the pitch [1]. The feature distinguishing futsal from traditional soccer is the fact that the play is stopped when the ball leaves the pitch or when a player commits an offence. Because of those stoppages, matches that are supposed to take  $2 \times 20$  min usually last up to 80 min [2]. What is more, there are differences in the types of the surfaces on which futsal and soccer matches are played. Futsal is usually played on surfaces made of flat, smooth and non-abrasive plastics (e.g. combi-elastic sports surface).

Futsal is a very dynamic sport in which energy from both aerobic and anaerobic sources is used. The kinematic analysis of a player's movements proves that just like soccer players, futsal players perform the following activities during a match: standing, walking, runs of

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low, medium and high intensity, and sprints [1, 3, 4]. On average, futsal players change the form of activity every 3.38 s, and perform sprints that last ca. 1.95 s and are separated by breaks of 79 s [3, 5]. Very often, the efficiency of an action depends on the time the players take to perform it. Therefore, efforts taken on the basis of anaerobic metabolism become key elements as they are more efficient if they are performed at a lower level of fatigue [1, 6–8]. When the efficiency of futsal players' efforts is taken into account, frequent changes turn out to be very important because they result in players performing efforts of an intensity of 85–91% of maximum heart rate ( $HR_{max}$ ), corresponding to 80–85% of maximal oxygen consumption ( $VO_{2max}$ ) for 83% of the time, for 16% of the time they take efforts of medium intensity (65–85%  $HR_{max}$ ) and for 0.3% of the time of low intensity efforts [5, 6]. The outfield players maintain the average of 75–90% of  $VO_{2max}$  [3].

Thanks to the possibility of frequent player substitutions in futsal, the amount of time each player spends playing and resting during the course of a game can be planned and controlled. The high intensity of the game affects the level of players' energy expenditure. The intensity of a game is commonly assessed by % $HR_{max}$  and a player's fatigue is measured by the Borg Scale of Perceived Exertion. The method shows correlations with HR and lactate [9]. Additionally, a player's subjective assessment is a simple diagnostic method which allows the evaluation of their level of recovery and readiness during rest breaks and after successive competitive matches. Top futsal players are characterized by fast post-exercise recovery. A decrease in heart rate (HR) to a certain level is one of the main elements of monitoring an organism's adaptation to physical effort [10]. According to Stupnicki et al. [11], the rate of the decrease depends on aerobic power, which enables recovery after anaerobic efforts, dominant in this type of effort. The analysis of the intensity and dynamics of players' restitution during breaks in real game conditions, in a championship match, not in laboratory conditions, should allow drawing conclusions about the optimal length of recovery breaks [12]. There is very little research into the field but it confirms that the intensity of efforts during a futsal match is changeable, that there are periods of very high intensity separated by breaks, during which intensity drops significantly. It allows for incomplete recovery and a decrease in HR, which makes it possible for a player to perform another effort at near maximum intensity [2].

The aim of the study was to assess, on the basis of HR measurements, the real intensity of the game, the players' energy expenditure during a match, and the dynamics of restitution during breaks in successive tournament matches. The analysis of the restitution dynamics in real game conditions will allow drawing practical conclusions to enable players to economize on their efforts so that they can spend more time on the pitch and play more efficiently.

## Material and methods

The studied group consisted of futsal players from an academic club at the University School of Physical Education in Wrocław, Poland. There were 11 players aged  $22.76 \pm 2.53$  years, their height was  $177.34 \pm 5.07$  cm, body mass  $74.8 \pm 8.04$  kg, BMI  $23.78 \pm 2.7$  kg/m<sup>2</sup>, and they had played futsal for  $12.32 \pm 3.15$  years. The study was carried out during the semi-finals of the Academic National Futsal Championship in Katowice, Poland. The team consisted of players who had already won gold medals at the Academic National Futsal Championship. The study took place in January 2014. The players played 4 tournament matches in 2 days (2 matches per day): the 1<sup>st</sup> match in the morning session and the other one in the afternoon session. The matches were marked: 1<sup>st</sup> one – A, 2<sup>nd</sup> one – B, 3<sup>rd</sup> one – C, 4<sup>th</sup> one – D.

The players' HR was registered during the four matches. The HR was registered continuously and the measurement started with a pre-match warm-up and finished 5 min after each match. The Polar Team 2 system (Polar Electro Oy, Kempele, Finland) was used to register the data. Six successive efforts on the pitch during the matches, marked as 1E–6E, and six successive breaks, marked as 1R–6R, were analysed. Owing to the fact that recovery breaks were not of equal length, HR values up to the 3<sup>rd</sup> min of recovery were analysed. To analyse the dynamics of restitution, HR values at the time of a player leaving the pitch (0 s), as well as HR values registered at the 10<sup>th</sup>, 30<sup>th</sup>, 60<sup>th</sup>, 90<sup>th</sup>, 120<sup>th</sup>, 150<sup>th</sup>, 180<sup>th</sup> seconds of restitution after each break were taken into account. On the basis of the obtained results, the intensity of efforts expressed as absolute HR and % $HR_{max}$  was determined, as were the energy expenditure of single efforts, the total energy expenditure of all efforts (all substitutions), and the dynamics of restitution during breaks in the matches. The data were registered during four tournament matches. Lactate concentrations in the blood were also assayed: resting concentrations on the successive days of the tournament and at the 3<sup>rd</sup> minute after the end of each match. Blood was collected from the players' fingertips and the Lactate Scout system (Red Med, Poland) was used to determine lactate concentrations. For the measurement of the players' energy expenditure during a match, they had to perform an exercise test. Two weeks before the tournament, each player took part in a progressive test on a motorized treadmill. The test started with the initial speed of 6 km/h. The speed was increased by 2 km/h every 3 min for as long as the subject was able to continue running. During the test, the players' HR values and spirometric variables were registered with a Quark b2 (Cosmed, Italy) gas analyser. The values of  $VO_{2max}$  and  $HR_{max}$  registered during the test were then entered into the Polar Team 2 system, used during futsal matches. On the basis of the provided data, the Polar Team 2 calculated the value of energy expenditure, expressed in kcal/min.

Then, the energy expenditure of a single effort on the pitch in each match was assessed. The energy expenditure in each phase of the match was totalled, and energy expenditure was expressed as the sum of all the six phases. Energy expenditure during recovery breaks was not taken into account.

The Statistica 10.0 PL software was used for statistical analysis. The results were shown as means and standard deviations (*SD*). The ANOVA (Analysis of Variance) test was applied for single and multiple factor analysis, Duncan's test was used for the post-hoc analysis. The level of  $p < 0.05$  was considered statistically significant. The homogeneity of variance (Levene's test), as well as the normality Shapiro-Wilk test were used before performing the ANOVA.

## Results

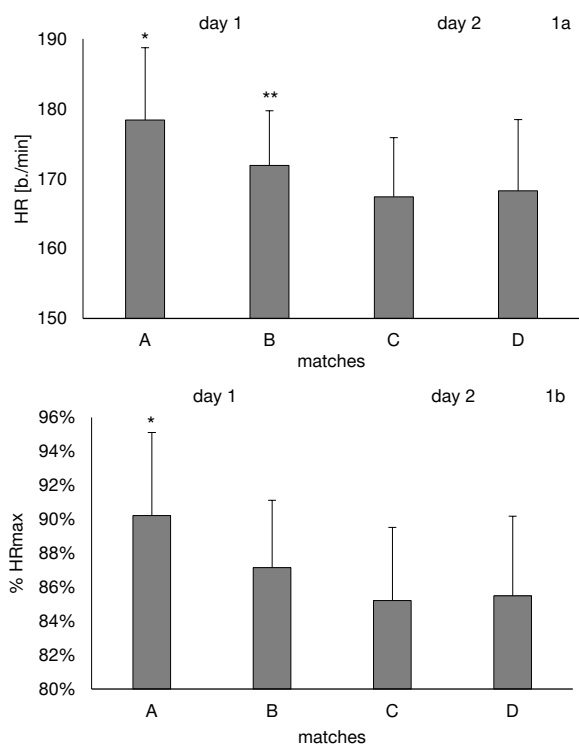
The highest intensity of efforts, assessed on the basis of HR values, was noted in match A (Figure 1a). The mean value of HR in the 1<sup>st</sup> match differed significantly in comparison with the mean value of HR observed in the other matches ( $p < 0.05$ ). The intensity of match B was significantly higher than that in matches C and D. There were no statistically significant differences between the intensity of matches C and D. The intensity in all the matches was in the range of 85–90% HR (Figure 1b, Table 1).

All match A results were characterized by highest intensity, even though in this match the intensity of ef-

forts 5E and 6E decreased significantly in comparison with the preceding four matches (Tables 1 and 2). While comparing the HR values of the corresponding efforts in the four matches, it was concluded that each effort in match A was more intense than the corresponding effort in the other matches. The players spent  $4:01 \pm 1:13$  min on the pitch. The longest period of time spent by a player on the pitch was noted in match C in effort 6E and it equalled  $5:08 \pm 1:31$  min, while the shortest one was in effort 4E, also in match C, and it equalled  $3:01 \pm 1:23$  min. The total time the players spent playing on the pitch in a match was  $24:12 \pm 6:53$  min. The players played the longest in matches A ( $25:36 \pm 5:29$  min) and C ( $25:36 \pm 7:55$  min), and the shortest in match B ( $22:26 \pm 6:14$  min).

The total energy expenditure of all the single efforts in the four matches was  $395.11 \pm 118.70$  kcal/match. The highest energy expenditure was registered in match A, and it equalled  $443.12 \pm 113.58$  kcal, while the lowest was observed in match B, and it equalled  $360.57 \pm 99.39$  kcal (Table 3). The mean energy expenditure of a single effort was  $16.33 \pm 5.36$  kcal/min. The players expended most energy in match A ( $17.31 \pm 4.71$  kcal/min) during a single effort on the pitch. The lowest energy expenditure was noticed in match C ( $15.86 \pm 5.24$  kcal/min). The analysis of all the matches shows that the highest energy expenditure was noted in efforts 1E of all the matches ( $17.19 \pm 4.92$  kcal/min), while the lowest was observed in efforts 5E of all the matches ( $15.93 \pm 5.96$  kcal/min).

The dynamics of restitution was the slowest in match A, and the fastest in match D. In match A, at the 180<sup>th</sup> second of each break, the value of HR decreased by  $28.45 \pm 3.90\%$  (Table 4). The least effective was the first break (1R), the value of HR decreased only by  $24.40 \pm 6.45\%$ . The most effective recovery in match A was registered after the last effort (6E), when the HR decreased by  $35.80 \pm 1.93\%$  (Figure 2a). In match B, the efficiency of recovery was  $28.33 \pm 2.50\%$  (Table 4). The least effective recovery occurred during the second break (2R) in match B – the HR decreased only by  $24.59 \pm 10.24\%$ , and the most effective one in the sixth break (6R) – the HR decreased by  $31.35 \pm 0.70\%$  (Figure 2b). The value of HR during the recovery break in match C decreased by  $30.84 \pm 3.58\%$  (Table 4). The slowest recovery was in the first break (1R) as the HR decreased by  $26.03 \pm 4.92\%$ , and the fastest – in the fifth break (5R), when the HR decreased by  $36.26 \pm 6.54\%$  (Figure 2c). As mentioned previously, the recovery in match D, the last match of the tournament, was the most effective. At the 180<sup>th</sup> second of recovery (1R–6R), the HR decreased by  $32.50 \pm 3.16\%$  and it was higher than at the 180<sup>th</sup> second of matches A and B (Table 4). In match D, the most effective was the sixth recovery break (6R), when the decrease in HR was  $37.77 \pm 1.60\%$  (Figure 2d). It was the most effective of all the registered recoveries during the four matches.



\* significant difference when compared with the other matches ( $p < 0.05$ )  
 \*\* significant difference when compared with matches C and D ( $p < 0.05$ )

Figure 1. Average HR values of each exertion (1a) and %HR<sub>max</sub> (1b) in the following matches

Table 1. Average values %HR<sub>max</sub> of six following efforts in matches A, B, C, and D

Matches		Exercise						$\bar{x}$ (1–6E) (%HR <sub>max</sub> )
		1E (%HR <sub>max</sub> )	2E (%HR <sub>max</sub> )	3E (%HR <sub>max</sub> )	4E (%HR <sub>max</sub> )	5E (%HR <sub>max</sub> )	6E (%HR <sub>max</sub> )	
A	$\bar{x}$ $\pm$ SD	90.29 $\pm$ 6.35	90.96 $\pm$ 5.25	91.15* $\pm$ 4.41	90.59** $\pm$ 3.55	89.05 $\pm$ 5.58	87.37 $\pm$ 3.67	90.22 $\pm$ 4.90
B	$\bar{x}$ $\pm$ SD	86.96 $\pm$ 5.29	87.40 $\pm$ 2.70	85.85 $\pm$ 5.20	87.43 $\pm$ 4.35	88.36 $\pm$ 1.82	87.11 $\pm$ 3.84	87.15 $\pm$ 3.97
C	$\bar{x}$ $\pm$ SD	86.80 $\pm$ 4.66	87.27 $\pm$ 3.29	82.80 $\pm$ 2.24	82.90 $\pm$ 4.60	84.40 $\pm$ 5.61	83.14 $\pm$ 6.71	85.21 $\pm$ 4.32
D	$\bar{x}$ $\pm$ SD	86.18 $\pm$ 3.79	83.40 $\pm$ 5.39	85.70 $\pm$ 5.57	86.42 $\pm$ 4.73	84.51 $\pm$ 4.86	86.65 $\pm$ 5.44	85.50 $\pm$ 4.69

\* significant difference when compared with 3E from match C ( $p < 0.05$ )\*\* significant difference when compared with 4E from match C ( $p < 0.05$ )

E – effort

Table 2. Average HR values of six following efforts in matches A, B, C, and D

Matches		Exercise						$\bar{x}$ (1–6E) (b/min)
		1E (b/min)	2E (b/min)	3E (b/min)	4E (b/min)	5E (b/min)	6E (b/min)	
A	$\bar{x}$ $\pm$ SD	178.52 $\pm$ 13.10	179.87 $\pm$ 11.32	180.37* $\pm$ 8.99	179.29** $\pm$ 7.90	176.25 $\pm$ 12.18	171.67 $\pm$ 7.06	178.39 $\pm$ 10.37
B	$\bar{x}$ $\pm$ SD	171.48 $\pm$ 9.89	172.54 $\pm$ 5.29	169.49 $\pm$ 10.51	173.76 $\pm$ 8.56	173.90 $\pm$ 3.61	169.64 $\pm$ 8.04	171.91 $\pm$ 7.83
C	$\bar{x}$ $\pm$ SD	170.78 $\pm$ 9.90	171.11 $\pm$ 7.08	162.70 $\pm$ 4.57	162.88 $\pm$ 9.11	166.42 $\pm$ 8.30	162.46 $\pm$ 11.35	167.40 $\pm$ 8.47
D	$\bar{x}$ $\pm$ SD	169.80 $\pm$ 8.46	165.88 $\pm$ 11.87	168.64 $\pm$ 12.11	170.05 $\pm$ 10.50	166.29 $\pm$ 10.44	169.60 $\pm$ 12.09	168.27 $\pm$ 10.21

\* significant difference when compared with 3E from match C ( $p < 0.05$ )\*\* significant difference when compared with 4E from match C ( $p < 0.05$ )

E – effort

Table 3. Average energy expenditure of the following exertions, total and average energy expenditure in each match

Matches		Exercises							$\Sigma$ (1–6E) (kcal/match)
		1E (kcal/min)	2E (kcal/min)	3E (kcal/min)	4E (kcal/min)	5E (kcal/min)	6E (kcal/min)	$\bar{x}$ (1–6E) (kcal/min)	
A	$\bar{x}$ $\pm$ SD	17.72 $\pm$ 6.80	17.74 $\pm$ 6.05	17.81 $\pm$ 2.43	17.39 $\pm$ 4.23	17.20 $\pm$ 4.37	16.39 $\pm$ 3.20	17.31* $\pm$ 4.71	443.12 $\pm$ 113.58
B	$\bar{x}$ $\pm$ SD	17.87 $\pm$ 2.29	15.45 $\pm$ 1.45	14.93 $\pm$ 5.17	16.85 $\pm$ 7.18	15.00 $\pm$ 5.64	16.03 $\pm$ 4.11	16.10 $\pm$ 5.46	360.57 $\pm$ 99.39
C	$\bar{x}$ $\pm$ SD	16.90 $\pm$ 6.05	16.64 $\pm$ 2.24	15.11 $\pm$ 5.16	15.17 $\pm$ 6.41	15.82 $\pm$ 7.58	15.54 $\pm$ 5.94	15.86 $\pm$ 5.24	406.12 $\pm$ 139.87
D	$\bar{x}$ $\pm$ SD	16.25 $\pm$ 4.57	15.82 $\pm$ 6.25	16.30 $\pm$ 5.49	16.20 $\pm$ 8.31	15.68 $\pm$ 6.26	16.24 $\pm$ 0.86	16.04 $\pm$ 6.02	370.64 $\pm$ 121.98
A–D	$\bar{x}$ $\pm$ SD	17.19** $\pm$ 4.92	16.41 $\pm$ 4.00	16.03 $\pm$ 4.56	16.40 $\pm$ 6.54	15.93 $\pm$ 5.96	16.05 $\pm$ 3.53	16.33 $\pm$ 5.36	395.11 $\pm$ 118.70

\* significant difference when compared with other matches ( $\bar{x}$  1–6E) ( $p < 0.05$ )\*\* significant difference when compared with  $\bar{x}$  A–D (5E) ( $p < 0.05$ )

E – effort



Table 4. Restitution speed – HR(%) during the considered time periods of matches A, B, C, and D

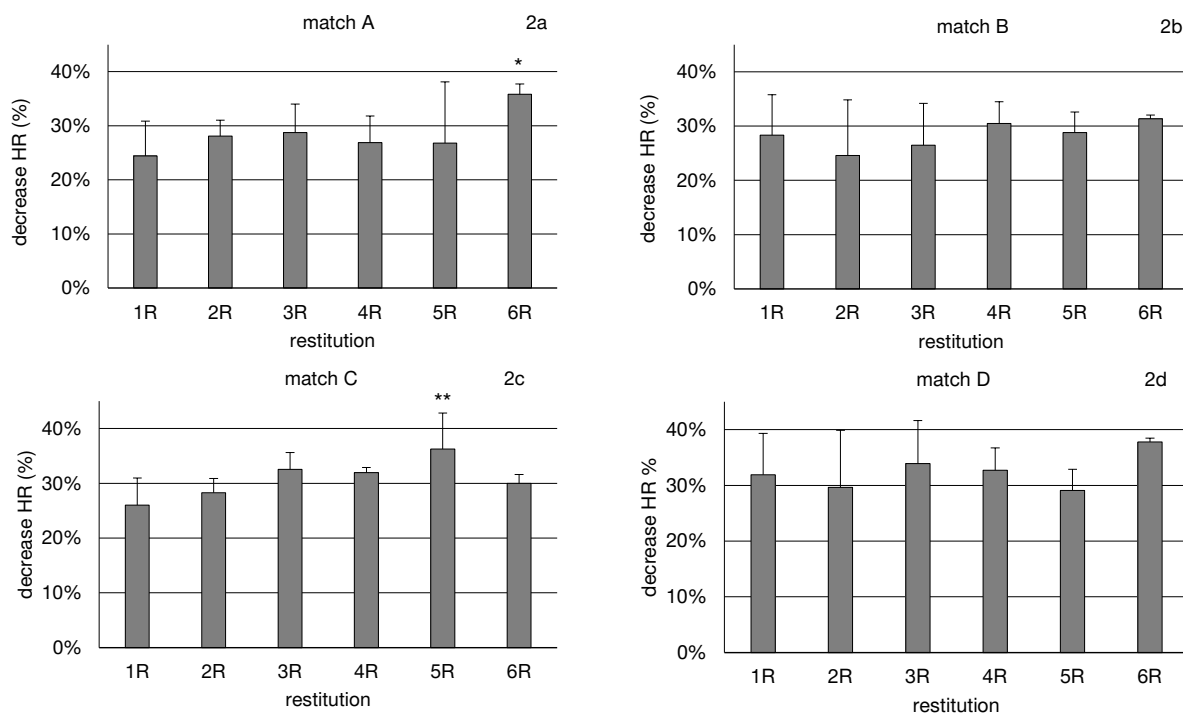
Matches	Restitution							
		10 (s)	30 (s)	60 (s)	90 (s)	120 (s)	150 (s)	180 (s)
A	$\bar{x}$ $\pm SD$	0.65 $\pm 0.54$	9.90** $\pm 0.98$	18.18** $\pm 1.20$	23.59† $\pm 1.55$	25.72† $\pm 2.52$	28.05 $\pm 2.61$	28.45 $\pm 3.90$
B	$\bar{x}$ $\pm SD$	1.97* $\pm 0.52$	13.62 $\pm 3.36$	22.04 $\pm 2.22$	25.38 $\pm 1.70$	26.96 $\pm 1.15$	27.58 $\pm 2.05$	28.33 $\pm 2.50$
C	$\bar{x}$ $\pm SD$	1.21 $\pm 0.57$	13.96 $\pm 2.61$	23.35 $\pm 1.10$	27.93 $\pm 2.28$	29.89 $\pm 1.97$	30.78 $\pm 3.04$	30.84 $\pm 3.58$
D	$\bar{x}$ $\pm SD$	1.89* $\pm 0.77$	16.33 $\pm 3.33$	23.02 $\pm 3.27$	28.29 $\pm 2.66$	29.46 $\pm 2.06$	31.92†† $\pm 1.83$	32.50†† $\pm 3.16$

\* significant difference when compared with 10 s, match A and C ( $p < 0.05$ )

\*\* significant difference when compared with 30 s and 60 s, match B, C, and D ( $p < 0.05$ )

† significant difference when compared with 90 s and 120 s, match C and D ( $p < 0.05$ )

†† significant difference when compared with 150 s and 180 s, match A and B ( $p < 0.05$ )



\* significant difference when compared with break 1R, match A ( $p < 0.05$ )

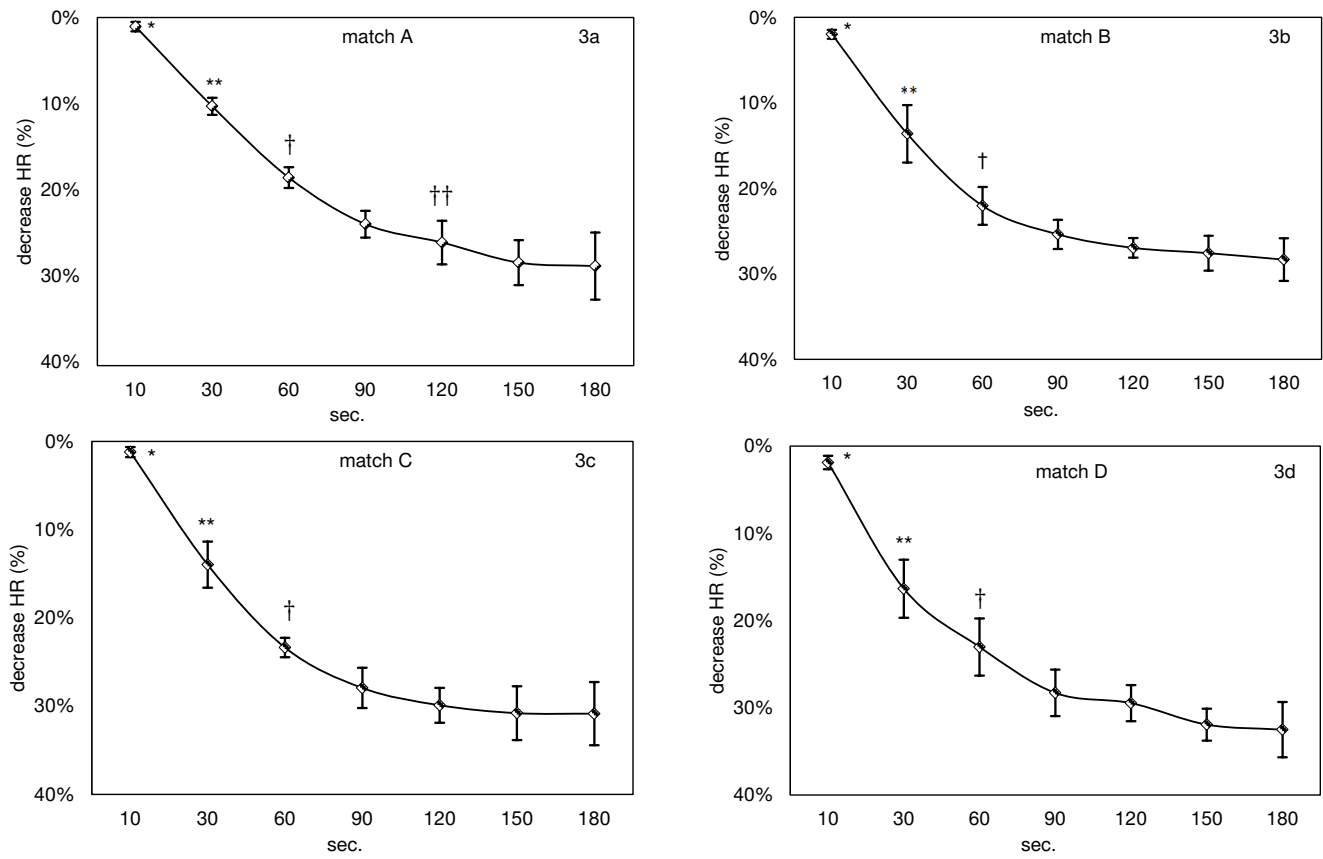
\*\* significant difference when compared with break 1R, match C ( $p < 0.05$ )

R – break

Figure 2. Decrease of the HR (%) values in following resting brakes measured in 180 s compared with the values in the moment of leaving the pitch (0 s) in each match

In each of the matches, the dynamics of restitution was analysed within 0–180 s. After 10 s of recovery, the highest decrease in the value of HR was registered in match B, the lowest one in match A. At the 30<sup>th</sup> second, the highest drop in the HR value was noted in match D, and the lowest in match A. At the 60<sup>th</sup> second of match C, the highest decrease in HR was observed, and the lowest in match A. In the fourth interval (90 s) once again the least effective recovery was in match A, and the most effective one in match D. After 120 s,

a decrease in HR in match C turned out to be the highest, while the lowest one was again registered in match A. In the last two time periods – 150 s and 180 s – the recovery was the most effective in match D, and the least effective in match B. While analysing the dynamics of restitution in each match (Figure 3), the researchers came to the conclusion that in match A the rate of recovery stabilized between the 150<sup>th</sup> and 180<sup>th</sup> second, and at that time no statistically significant differences were registered between the HR values. In matches B, C,



\* significant difference when compared with 30 s, other matches ( $p < 0.05$ )  
 \*\* significant difference when compared with 60 s, other matches ( $p < 0.05$ )  
 † significant difference when compared with 90 s, other matches ( $p < 0.05$ )  
 †† significant difference when compared with 150 s, match A ( $p < 0.05$ )

Figure 3. The dynamics of restitution – HR(%) in the analysed time points

Table 5. Average HR drop (%) in the analysed time periods in each match

Restitution		Time						
		10 (s)	30 (s)	60 (s)	90 (s)	120 (s)	150 (s)	180 (s)
1R	$\bar{x}$ A–D	1.73*	15.27**	22.17†	26.85	27.27	27.89	27.66
	$\pm$ SD	$\pm$ 0.58	$\pm$ 3.37	$\pm$ 2.73	$\pm$ 3.06	$\pm$ 2.28	$\pm$ 1.94	$\pm$ 3.24
2R	$\bar{x}$ A–D	1.55*	11.88**	20.53†	24.42§	27.34	27.97	27.64
	$\pm$ SD	$\pm$ 0.50	$\pm$ 1.56	$\pm$ 2.00	$\pm$ 1.14	$\pm$ 0.81	$\pm$ 2.07	$\pm$ 2.15
3R	$\bar{x}$ A–D	1.15*	12.06**	20.02†	26.58§	28.22	29.98	30.41
	$\pm$ SD	$\pm$ 0.45	$\pm$ 3.80	$\pm$ 2.37	$\pm$ 4.06	$\pm$ 3.67	$\pm$ 3.83	$\pm$ 3.41
4R	$\bar{x}$ A–D	1.77*	15.05**	22.98†	27.48§§	28.76	29.74	30.50
	$\pm$ SD	$\pm$ 0.93	$\pm$ 3.83	$\pm$ 4.33	$\pm$ 3.82	$\pm$ 3.56	$\pm$ 2.53	$\pm$ 2.60
5R	$\bar{x}$ A–D	1.43*	14.49**	22.23††	26.18	27.00	30.26	30.24
	$\pm$ SD	$\pm$ 1.07	$\pm$ 4.66	$\pm$ 2.49	$\pm$ 2.33	$\pm$ 2.55	$\pm$ 3.92	$\pm$ 4.15
6R	$\bar{x}$ A–D	0.95*	12.00**	21.96†	26.27§	29.43§§	31.64	33.73
	$\pm$ SD	$\pm$ 1.12	$\pm$ 3.15	$\pm$ 3.70	$\pm$ 2.15	$\pm$ 2.39	$\pm$ 2.76	$\pm$ 3.66

\* significant difference when compared with 30 s, 60 s, 90 s, 120 s, 150 s, 180 s ( $p < 0.05$ )  
 \*\* significant difference when compared with 60 s, 90 s, 120 s, 150 s, 180 s ( $p < 0.05$ )  
 † significant difference when compared with 90 s, 120 s, 150 s, 180 s ( $p < 0.05$ )  
 †† significant difference when compared with 120 s, 150 s, 180 s ( $p < 0.05$ )  
 § significant difference when compared with 150 s, 180 s ( $p < 0.05$ )  
 §§ significant difference when compared with 180 s ( $p < 0.05$ )

and D, the rate of recovery stabilized after 90 s. There were no statistically significant differences in the HR values between the 120<sup>th</sup> and 150<sup>th</sup> second or between the 150<sup>th</sup> and 180<sup>th</sup> second. In matches B, C, and D, the fast phase of recovery finished at the 90<sup>th</sup> second, whereas in match A, in which the intensity of the successive efforts was the highest, the fast phase of recovery finished only at the 150<sup>th</sup> second.

Table 5 shows the dynamics of restitution expressed as % of HR reduction in time. The data are the mean % values of HR reduction during recovery in all the matches. Thorough analysis indicates that in all six recovery breaks, the first phase (fast) lasted up to 90 s, and the slow phase started after 90 s and lasted until the moment of substitution. The conclusion is based on the fact that the differences in the dynamics of restitution (reduction in %HR) between the time intervals of 10–30 s, 30–60 s, 60–90 s in each of the breaks separately (1R, 2R, 3R, 4R, 5R, 6R) became statistically significant. In the time intervals of 10–30 s and 30–60 s, there were significant differences between the values of % reduction in HR and the level of significance was  $p < 0.0001$ . However, in the time interval of 60–90 s, the significance was the following: 1R:  $p < 0.001$ , 2R:  $p < 0.009$ , 3R:  $p < 0.002$ , 4R:  $p < 0.000$ , 5R:  $p < 0.046$ , 6R:  $p < 0.020$  (Table 5). On the basis of the obtained data, it is impossible to conclude that the dynamics of restitution in the same time intervals was significantly slower or faster during any of the breaks.

In the study, we also measured the rate of perceived exertion (RPE) in Borg scale after each match and the lactate concentration in the following days of the tournament and 3 min after each match end. The analysis of RPE after successive matches did not show any statistically significant differences. The players perceived all the matches as very hard. In their opinion, match C ( $15.1 \pm 1.52$ ) was the hardest, even though the mean values of HR and %HR<sub>max</sub> noted in this match were the lowest. The value was  $14 \pm 2.61$  in match A,  $13.91 \pm 2.66$  in match B, and  $13.89 \pm 1.05$  in match D. There were no statistically significant differences between resting lactate concentrations on the two successive days of the tournament (1<sup>st</sup> day,  $2.04 \pm 0.58$  mmol/l; 2<sup>nd</sup> day,  $1.98 \pm 1.06$  mmol/l) and the day after the tournament (3<sup>rd</sup> day,  $1.75 \pm 1.04$  mmol/l). Post-exercise lactate concentrations (match A,  $8.19 \pm 4.56$  mmol/l; match B,  $6.99 \pm 1.79$  mmol/l; match C,  $6.84 \pm 4.81$  mmol/l; match D,  $6.71 \pm 1.96$  mmol/l) were lower after each successive match, which confirmed a decrease in the effort intensity from match to match observed in the HR changes. The values of VO<sub>2max</sub> in that group was  $51.15 \pm 4.10$  ml/min/kg. The HR<sub>max</sub> in the test was  $197.71 \pm 9.87$  BPM. The subjects finished the progressive test between 16 and 20 km/h ( $17.09 \pm 1.31$  km/h).

## Discussion

The growing popularity of futsal will require constant improvements on the part of the players in their level of sports competition. To meet the demands, it is essential to increase the quality of the training process and adjust it to the real-life competition conditions. Therefore, it is necessary to analyse the physiological processes which are involved in the efforts typical of the game [3, 12, 13]. The characteristic feature of futsal, which is a team sport, is a greater concentration of players on the pitch during matches in comparison with 11-a-side soccer. Thus the players are forced to move constantly and look for some space in order to play effectively. In consequence, they have to perform very intensive efforts. The observations are confirmed by our study, in which the mean intensity of all the efforts in four tournament matches was  $87.35 \pm 4.94\%$  HR<sub>max</sub>. Very high mean intensity was registered in match A ( $90.22 \pm 4.90\%$  HR<sub>max</sub>) (Figure 1b). It is much higher than the intensity observed in 11-a-side soccer [3, 6, 14]. In this very dynamic sport, frequent substitutions make it possible for players to maintain a high intensity of efforts, as well as to recover faster [1, 7].

Our subjects performed their efforts in the range of  $4:01 \pm 1:13$  min. Duarte et al. [2] confirmed that in a small sided game 4 v 4 lasting 4 min, the players spent almost 60% of the time in the zone above 85% HR<sub>max</sub>. In our study, the intensity of single efforts was higher (Table 2). However, it should be noticed that the effort is very asynchronous, the changes in intensity are significant, and it is quite repetitive [3]. Therefore, it is crucial to choose optimal recovery times so as to enable players to recover as soon as possible, and, on the other hand, to make it possible for outfield players to maintain efforts of the intensity necessary to meet the demands of the game [2].

The system of tournament matches is organized in such a way that the first match becomes a key one for the successive phases [5]. Therefore, the mean intensity of efforts performed by our subjects in the first match was the highest –  $90.22 \pm 4.90\%$  HR<sub>max</sub> (Figure 1b), and it is higher than that in the First League futsal players who participated in the Brazilian study [15]. The registered intensity of the Brazilian players was  $86.4 \pm 3.8\%$  HR<sub>max</sub>. It can be assumed that apart from sports competition, the value is influenced by many factors, like emotions or additional motivation to win the first match [3, 6]. A win in the first match can provide players with some psychological comfort before another phase of the tournament. Players should also be the most rested before the first match. Additionally, the coach's verbal support can have a great influence on the intensity of efforts [16]. The investigation by Makaje et al. [17] shows how important motivation and proper psychological approach are. Players from an academic team took part in a game simulation and the values of HR registered during the game reached  $86.2 \pm 6.7\%$  HR<sub>max</sub>.

This is confirmed by the HR values observed in our study in match A in each effort performed after a return substitution, match A being the most intensive effort in the whole tournament. The high dynamics and intensity of efforts taken by our subjects were also reflected in their energy expenditure. A player expended  $17.19 \pm 4.92$  kcal/min on the first effort of each match, whereas the mean value of all the efforts in the tournament was  $16.33 \pm 5.36$  kcal/min (Table 3). The total energy expenditure observed in our study ranged from  $360.57 \pm 99.39$  to  $443.12 \pm 113.58$  kcal/match (Table 3) and was significantly higher than that noted during other official futsal matches. The total energy expenditure in the research by Rodrigues et al. [15] was  $313 \pm 9.3$  kcal/match. The first match of the tournament (A) in our study was also the only match in which the mean intensity of efforts (1E, 2E, 3E, 4E) exceeded 90% HR<sub>max</sub>, and this could be classified as very high intensity (Figure 1, Tables 1 and 2) [18]. The incurred energy expenditure should be compared with each player's efficiency during a game. When further research of this kind is done, analysis should be performed of the effectiveness of individual actions undertaken by players on the pitch (i.e. 1 v 1 actions in offensive and defensive, efficiency of passes and shots at the goal). The analysis could be key to the evaluation of the significance of the incurred energy expenditure and the efficiency of the undertaken actions which can directly influence the end result of a game.

It is possible for coaches to monitor the players' HR during matches and to make decisions about substitutions and recovery breaks on the basis of the obtained data. Our study shows that the intensity of efforts was lowest in match C. Even though it equalled  $85.21 \pm 4.32\%$  HR<sub>max</sub> (Figure 1b), the players perceived the match as the most exhausting. It should be remembered that it is a very important match for the next phases of the tournament. The occurrence of fatigue in this match is confirmed by lactate concentrations in the muscles (Figure 2b) and the subjective rating of exertion on the Borg Scale of Perceived Exertion ( $15.1 \pm 1.52$ ) (Figure 3). This fact, now supported by our findings, should make coaches realize the importance of the right choice of tactics and players' motivation before such a strategically significant match. The lowest individual intensity was registered in the last match of the tournament, which was not important for the players as the team had not proceeded to the next stage of the tournament.

Repeated Sprint Ability (RSA) enables players to obtain energy from anaerobic glycolysis, which fosters lactate concentration in the muscles [4, 19]. In our players, lactate concentration in the blood after match A was  $8.19 \pm 4.56$  mmol/l (Figure 2b). After successive matches, the concentration decreased (Figure 2b). Lower lactate concentrations correspond with lower intensity of efforts registered in consecutive matches. Therefore, it can be concluded that the general ability of players to perform at high intensity decreased. Under conditions

of fatigue, the ability of the contracting muscles to be fully mobilized is impaired, which in turn leads to a decrease in the intensity and number of sprints performed by players [5, 9, 19]. In matches where unlimited, multiple return substitutions are allowed, individual players' ability to recover becomes of key importance. The amount of time a player needs to recover may determine the frequency of substitutions. The sooner a player's organism reaches near baseline parameters, the sooner they will be able to return onto the pitch [20]. Therefore, it could be assumed that a coach should be interested in shorter breaks, during which the recovery effect is most noticeable in the earlier phase of restitution. To make it happen, each player needs to have a great aerobic capacity, which is the main factor determining the rate of recovery and 'repayment' of the oxygen debt (EPOC, excess of postexercise oxygen consumption) [21]. In our study, we observed that at the intensity of 85–87% HR<sub>max</sub> (Figure 1b), within the ranges we registered in matches B, C, and D, the slow phase of recovery started at ca. 90<sup>th</sup> second, enabling the player to return onto the pitch (Figure 3, Tables 4 and 5). However, the higher intensity of ca. 90% HR<sub>max</sub>, which was noted in match A (Figure 1b), results in the slow phase of recovery beginning much later. According to our study, it happens in the 150<sup>th</sup> second of recovery (Figure 3).

According to the principle of heterochronicity of recovery, different systems need different amounts of time to return to their baseline parameters, as the process is contingent on individual players' genetic features and their levels of physical performance [22]. The nervous system is the first to recover, then goes the respiratory system, the circulatory system, and the muscular system. During recovery, the organism's energy substrates are resynthesized [20]. Our study seems to confirm the thesis that the efficiency of restitution is dependent on multiple factors. Features which may differentiate the character of recovery between individual players are the players' motor profiles, their position on the pitch, volitional acts, physical condition on the day of the match, or the current level of fatigue, the score, or tactical tasks [22]. Other factors may include long lasting fatigue and muscular micro-injuries, which adversely affect the economy of movement [7, 23].

Owing to a dynamic development of futsal, both practitioners and scientists are constantly faced with new demands as they are expected to find answers to questions in order to enrich the current state of knowledge about this sport. Practical knowledge will help practitioners prepare their players better for more effective efforts during futsal matches. In order to provide futsal trainers with a complete set of practical, applicable solutions, the analysis of individual actions undertaken by players should be included in further research, and correlations between their effectiveness and %HR<sub>max</sub>, fatigue (RPE and lactate concentration), and recovery processes should be studied.



## Conclusions

The analysis of the obtained results allows to draw the following practical conclusions:

1. The intensity of efforts in the first match (A) was  $90.22 \pm 4.90\%$   $HR_{max}$  and it was significantly higher than the intensity in matches B, C, and D. However, there were no significant differences in the mean time of the efforts ( $4:01 \pm 1:13$  min) undertaken in different matches. Therefore, it should be concluded that an appropriate reduction in the time players spend on the pitch during their successive efforts in one match and the consecutive tournament matches can result in reducing the decrease in effort intensity.

2. The fast phase of restitution in efforts of an intensity of ca. 85–87%  $HR_{max}$  ends after ca. 90 s, and the slow phase begins. At the intensity of ca. 90%  $HR_{max}$ , the fast phase starts after ca. 150 s (1 min later). At the very high level of intensity, a small increase in intensity results in a significant lengthening of the recovery time.

3. Owing to players' huge energy expenditure in matches during futsal tournaments (in our study, it was  $16.33 \pm 5.36$  kcal/min), it is necessary to provide them with food and proper supplementation to replenish energy stores and reduce the effects of growing fatigue. To prove the correctness of the conclusion, a separate study should be carried out.

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