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Assessment of Physiological Responses and Their Relationship with Technical-Tactical Performance among Polish National Team Athletes in Fighting Mode during the Ju-Jitsu World Championships

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Abstract
Introduction. The confrontation in sports ju-jitsu, in the fighting mode, is characterized by variable exertion, acyclic work, and frequent changes in combat conditions, which have a comprehensive impact on the athlete's body, triggering a cascade of physiological processes. The aim of the study was to assess the level and identify the nature of the relationships between selected physiological variables and technical-tactical performance during a high-level championship tournament among members of the Polish national ju-jitsu team.

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Materials and Methods. The study involved 10 ju-jitsu athletes, members of the national team (age: 27.7 ± 4.1 years; height: 181.2 ± 7.8 cm; body weight: 82.8 ± 8.6 kg; 18.8 ± 4.5 years of training). During the 2016 World Ju-Jitsu Senior Championships, measurements of lactic acid concentration and heart rate were taken before and after the sports combat. Tournament fights were recorded with specialized cameras, and then, based on retrospective analysis, technical-tactical indices (for three parts of the fight) were calculated and assessed for relationships with the recorded physiological variables.
Results. In the course of the analyses, significant differences ($p < 0.001$) were demonstrated before and after the fight in lactic acid concentration levels (2.89±0.31 vs. 17.5±2.9 mmol·L^{-1}) and heart rate variables (98.8±2.78 vs. 170.4±8.83 bpm). Additionally, significant negative and strong correlations were found between technical-tactical performance and lactic acid concentration for the variable of attack efficiency in Part I of the fight (Ae Part I: $r = -0.64$; $p < 0.05$) and the average efficiency from the three stages of the bout (Average Ae: $r = -0.71$; $p < 0.05$). A similar set of relationships was shown for the comparison of heart rate variables with technical-tactical performance, where significant, strong, and negative correlations were noted for attack effectiveness in Part II of the bout/fight (Ea Part II: $r = -0.88$; $p < 0.001$) and the average attack effectiveness from Parts I, II, and III of the bout t (Average Ea: $r = -0.82$; $p < 0.001$).
Conclusions. The fight induced significant activity in the physiological variables examined (heart rate and lactate levels). The decrease in attack effectiveness was accompanied by increasing lactate levels, while the decrease in effectiveness in Part II and the average across all three parts of the fight was associated with an increase in heart rate. Due to the tournament nature of the sport, it is recommended to intensify training programs that include heart rate control after a fight to improve post-exercise recovery and optimize efficiency in the later stages of the tournament. Additionally, it is advised to implement measures aimed at increasing tolerance to functioning under conditions of elevated lactate levels and increased heart rate.

Introduction

A bout in sport fighting ju-jitsu in the fighting variant is characterized by acyclic work and frequent changes in the conditions of the fight, which holistically affects the practitioners and engages the entire body comprehensively, activating all muscle groups [Ambrozy *et al*. 2014; Ambrozy *et al*. 2017]. The dynamically changing fight situation requires the athlete to quickly and swiftly respond to the opponent's counteractions, involving variable intensity effort and a wide variety of movements. In the fighting variant of ju-jitsu, success in combat is determined by the effectiveness of the techniques performed and the mistakes made by the opponent. The key to effectiveness is comprehensive technical-tactical preparation, as the bout takes place in three phases. Achieving sports mastery is possible through proper technical preparation based on motor skills, and the factor that decides the victory in a balanced sports match between athletes of similar levels is the fight strategy [Bocioaca 2014]. Analyzing thematic publications, it is noted that in the model of preparing a ju-jitsu athlete, the largest share is in technical-tactical preparation (31.3%) and physical preparation (including body composition and physical fitness, 28.4%), while theoretical (25.5%) and psychological preparation (14.8%) play a lesser role [Sterkowicz 1998; Ambrozy 2008].

One of the sources of energy for muscle contraction, which forms the foundation of human movement and activity, is a process called glycolysis. Glycolysis is the process in which glycogen is broken down into pyruvic acid and lactic acid. This is an exergonic process, meaning it releases energy, which is then used to convert ADP into ATP [Ronikier 2001; Chandel, Glycolysis 2021]. The ATP nucleotide will ultimately be used to fuel muscle contraction and other processes, including the creation of phosphocreatine stores [Nirody *et al*. 2020]. During intense efforts such as sport fighting in ju-jitsu, anaerobic energy utilization primarily comes from glycolysis, which allows for quicker energy release [Ambrozy 2008]. In this way, most of the energy used during intense efforts lasting longer than 5-10 seconds but shorter than 1-2 minutes comes from anaerobic glycolysis. Consequently, the glycogen content in muscles will decrease, and lactic acid concentration will increase. After the effort, metabolic oxidation reactions occur, which are used to convert about 4/5 of the lactic acid back into glucose [Chapelot, Charlot 2019]. Despite extensive knowledge about the physiological processes occurring in the human body during anaerobic exercise, such as ju-jitsu fighting, increased lactic acid concentration in the blood has not been analyzed as a factor potentially co-occurring with reduced efficiency, activity, and effectiveness during fights in world-class athletes. Scientific literature suggests that increased lactic acid concentrations may affect cognitive abilities [Coco *et al*. 2019] and motor skills [Moscatelli *et al*. 2016; Rydzik *et al*. 2022; Kachenkova *et al*. 2023], which influence the course of a fight in ju-jitsu athletes [Kedra *et al*. 2023]. Moreover, in a similar combat form like judo, even minimal lactic acid production defines poorer performance in terms of short-term memory due to the conditioning of the athletes' strategic abilities [Coco *et al*. 2018]. This might be associated with protective effects on the brain but at the cost of efficiency in other brain areas [Coco *et al*. 2016].

Such situations (stress and exertion in sports competitions) cause an increase in heart contraction frequency [Gorski 2017]. HR is one of the most important objective indicators of internal training load [Sozanski 1999; Halson 2014]. According to Slimani [Slimani *et al*. 2018], HR measurement among combat sport athletes should be combined with other tools such as lactic acid samples, metabolic thresholds, time and movement characteristics, or ratings of perceived exertion to obtain a more precise quantification of load during bouts and to estimate energy expenditures.

Since it was mentioned that there is a lack of current scientific studies comparing physiological parameters

with efficiency, activity, and effectiveness during different parts of the fight, it was decided to fill this research gap by conducting a physiological analysis of ju-jitsu athletes (Polish National Team members) in relation to the course of the sports fight. The identification of potential deficits in technical-tactical preparation and the area of physiological potential among top-level players in championship tournaments may have practical implications for coaches and the players themselves in the future [Sterkowicz, Maslej 1999; Poliszczuk 2002; Adam *et al*. 2012]. The aim of the study was to assess the level and identify the nature of the relationships between selected physiological variables and technical-tactical performance during a high-level championship tournament among members of the Polish national ju-jitsu team. The results of this study should highlight the trend of positive coexistence between selected physiological parameters and the level of technical-tactical preparation. Consequently, this may contribute to the improvement of these variables, aiming at achieving better sports performance.

Materials and Methods

Study participants and events

The analysis of physiological parameters and the level of technical-tactical training was conducted on athletes from the Polish National Team (n=10). The average height of the examined athletes was 181.2±7.8 cm, body weight: 82.8±8.6 kg, the average age was 27.7±4.1years, and their training experience averaged 18.8±4.5 years. The inclusion criteria included: membership in the Polish National Team in Ju-Jitsu; participants must have at least 15 years of training experience in ju-jitsu; participants must provide written consent to participate in the study and for their personal data to be processed for research purposes; participants must have regularly participated in training and sports competitions over the past two years. The exclusion criteria included: athletes who, despite competing, were not classified as National Team members; athletes with current injuries, chronic illnesses, or other health issues that may affect the study results; individuals who do not provide written consent to participate in the study and for their personal data to be processed.

The research material for evaluating the course of the fight consisted of multimedia recordings of sports fights that took place during the Senior World Ju-Jitsu Championships (fighting formula) on November 25th and 26th, 2016, in Wroclaw. A total of 3 fights per participant (n=3) were analyzed, which resulted in 30 fights being evaluated in total (n=30). The competition was conducted in accordance with the regulations of the International Ju-Jitsu Federation (JJIF) [Ju-Jitsu International Federation 2023].

Physiological measurements

Measurement of Blood Lactate Concentration

Measurements were taken at two-time points, namely before the fight (immediately before the warm-up) and after the tournament fight (immediately after the referee's verdict, with a break between the end of the fight and the verdict being less than 60 seconds). Three measurement cycles were performed (before and after each of the three fights fought by each participant), and the average value was taken for evaluation. Breaks between fights ranged from 60 to 120 minutes. Blood samples were taken from the fingertips of the subjects. These procedures were performed by a qualified nurse. The Lactate Scout analyzer (EKF Diagnostics, Barleben, Germany) was used for diagnosis.

Regarding the athletes studied, one month before the tournament, blood lactate concentration was measured over a one-week training period (measurements taken on 5 days). The average value was 1.83±0.49 $mmol \cdot L^{-1}$.

Measurement of Heart Rate

Measurements were taken three times before and after each fight, at two-time points: resting heart rate before the fight (immediately before the warm-up) and after the tournament fight (immediately before the referee's verdict). The averaged values were assessed. The athletes' heart rates were monitored using a Garmin Forerunner 235 device (Garmin Ltd., Olathe, Kansas, USA), which measures heart rate directly on the wrist using an optical sensor. The variable was recorded for a period of 10 to 30 seconds.

Regarding the athletes studied, one month before the tournament, resting heart rate was measured over a one-week training period (measurements taken on 5 days). The average value was 71.5±4.6 bpm.

Measuring the indicators of technical and tactical training

Analysis of bouts was performed based on digital recordings of tournament fights of the athletes in 2016. Offensive actions were analyzed quantitatively (Wazaari – 1 point; Ippon – 2 or 3 points) and recorded in different phases of the bout. Part I: Atemi-waza – strike – a standing position, Keri-waza – kicks; Pa–II: Nage-waza – throws, takedowns; Part III: Ne-waza – groundwork with the use of holds, chokes, and joint locks. Wazaari is a point awarded for a technique that was not executed perfectly but meets the effectiveness criteria, while Ippon is the highest score awarded for a perfectly executed technique (if Ippon is achieved in all three phases of the fight, the competition ends before the official fight time in favor of the athlete who accomplished it) [Ju-Jitsu International Federation 2023]. Three bouts of each athlete were analyzed. The recordings were made using three cameras (Sony HDR-CX115, Manufacturer, Tokyo, Japan). The video editing program Movavi Video Editor

14 was used to process the images. The setting of the cameras allowed for continuous observation of the fighting athletes, judges, and the scoreboard. A single spreadsheet was developed as a primary research tool. The data from the spreadsheets were entered into Excel software. A team of four Ju-Jitsu sports experts (three master class coaches and one internationally qualified referee) conducted a retrospective analysis of the recorded empirical material. Then, the values of indices of technical and tactical skills were calculated for all three stages of the bout. The formulas for calculating the indices were developed and based on the formulas used for judo, ju-jitsu, and kickboxing [Adam et al. 2012; Rydzik, Ambrozy 2021; Ambrozy et al. 2021a].

The technical and tactical profile in Ju-jitsu allows coaches to develop a training plan and an appropriate strategy for the athlete. The indicators of technical and tactical training were computed using the following formulas.

1. Effectiveness of the attack in the first or second part of the fight.
   EaF$^{(1 \text{ or } 2 \text{ part})}$ =
   n1 – number of attacks assessed with *waza-ari* points (1 point)
   n2 - number of attacks assessed with *ippon* points (2 points)
   1, 2 – point values of successful attacks
   N – total number of observed fights

2. Effectiveness of attack in the third part of the fight.
   EaF$^{(3 \text{ part})}$ =
   n1 – number of attacks assessed with waza-ari points (1 point)
   n2 - number of attacks assessed with ippon points (2 points)
   n3 – number of attacks assessed with ippon points (3 points)
   1, 2, 3 – point values of successful attacks
   N – total number of observed fights

3. Attack efficiency (the formula is the same for all parts of the fight [1;2;3])
   AeF$^{(1 \text{ or } 2 \text{ or } 3)}$ = x 100
4. Attack activity (the formula is the same for all parts of the fight [1;2;3]).
   $A_a^{F(1 \text{ or } 2 \text{ or } 3)}$ =
   – sum of attacks
   n – total number of fights by the athlete

The aim was to compare and evaluate the relationships between the sphere of indicators and the time structure, each match was divided into three active–passive segments. Using a stopwatch with an accuracy up to 1/100th of a second, the following times were measured:

1. Total Time (entire duration of the fight, including breaks) – measured from the referee's Hajime command (start of the fight) to the Matte command (signaling the end of the fight).
2. Break Time (breaks occurring between efforts in the fight) – measured from the Matte command (interrupting the competition) to Hajime (resumption of the match).
3. Effective Fight Time (difference between total time and breaks) – measured from the Hajime command (start or resumption of the match) to Matte (pause or end of the competition).

Bioethics Committee

Prior to participation in the tests, the participants were informed about the research procedures, which were in accordance with the ethical principles of the Declaration of Helsinki WMADH (2000). The participant's written consent was the inclusion criterion. The research was approved by the Bioethics Committee at the Regional Medical Chamber (No. 42/ KBL/OIL/2015 dated April 15, 2015).

Statistical analysis

The statistical analysis of the collected data was conducted using the Statistica v.13.1 software from Statsoft (Tibco). Basic descriptive statistics were calculated, including the mean, median, minimum and maximum values, standard deviation, and coefficient of variation. The degree of homogeneity within each group was assessed by interpreting the coefficient of variation values according to the following classification: V < 25% indicates low variability; 25 – 45% indicates moderate variability; 45–100% indicates high variability and >100% indicates very high variability. Spearman's Rank Correlation was used to assess the relationship between the variables studied. The inference thresholds for correlations are r = 0.0 to 0.19 for very weak correlation, r = 0.20 - 0.29 for weak correlation, r = 0.30 – 0.49 for moderate correlation, r = 0.50 – 0.79 for strong correlation, and r>0.80 for very strong correlation. The differentiation between lactate concentration and heart rate before and after the sports ***bout*** was assessed using the Student's t-test for the dependent variables. The choice of tests was preceded by checking the normality of variable distributions using the Shapiro –Wilk test, which indicated compliance of the distribution for the heart rate and lactate variables, and for the technical-tactical indicators variables significant deviation from normal distribution. A significance level of $p<0.05$ was considered statistically significant.

Results

Table 2 presents the basic descriptive statistics for attack activity (Aa), attack effectiveness (Ea), and attack effi-

ciency (Ae) across three parts (PART I, PART II, and PART III) and their averages. This detailed breakdown helps to understand the distribution and variability of attack activity, effectiveness, and efficiency across different phases of the fight and provides insight into the performance metrics of the athletes.

The presented results show that the highest Aa, Ea, and Ae values were achieved by the athletes in PART I.

Variability coefficients indicate that the subjects showed the greatest homogeneity in relation to Ae – Part I (low variability). The highest internal diversity was recorded for Ea – Part III (very high variability), as well as for Aa - Part III; Ea – Part II; Ae – Part II, III (high variability). For the remaining variables, moderate within-group variability was observed in terms of the achieved results.

Table 2. Basic descriptive statistics of attack activity, attack effectiveness, and attack efficiency

Indicator		Me	Min	Max	SD	$V_{\%}$
PART I Aa	11.14	9.13	7.33	18.67	4.28	38.43
PART II Aa	2.19	2.13	1.33	3.33	0.68	31.05
PART III Aa	0.68	0.67	0	1.25	0.36	52.25
Average from PART I, II, III	4.67	4.10	3.11	7.11	1.52	32.57
PART I Ea	7.07	6.71	4	13	2.50	35.39
PART II Ea	1.29	1.33	0	2	0.68	53.28
PART III Ea	0.59	0.45	0	2.5	0.74	126.63
Average from PART I, II, III	2.98	2.59	2.11	5.19	0.98	33.00
PART I Ae	46.20	47.89	25	59.29	10.10	21.87
PART II Ae	43.37	41.06	0	85.71	25.03	57.71
PART III Ae	44.17	41.67	0	100	38.50	87.17
Average from PART I, II, III	44.58	48.41	8.33	71.97	19.06	42.75

- arithmetic mean, Me - median, Min - minimum value, Max - maximum value, SD - standard deviation, V%- coefficient of variation.

Aa I - activity of the attack in the first part of the fight, Aa II - activity of the attack in the second part of the fight, Aa III - activity of the attack in the third part of the fight, Average Aa – average activity of the attack.

Ea I - effectiveness of the attack in the first part of the fight, Ea II - effectiveness of the attack in the second part of the fight., Ea III - effectiveness of the attack in the third part of the fight, Average Ea – Average effectiveness of the attack.

Ae I - efficiency of the attack in the first part of the fight, Ae II - efficiency of the attack in the second part of the fight, Ae III - efficiency of the attack in the third part of the fight, Average Ae – average efficiency of the attack.

The total average duration of bouts in the studied group was 248 seconds, ranging from 67 to 410.5 seconds. Of this, the average effective fight time was 140 seconds, while passive time (breaks) amounted to 108 seconds. The vast majority of confrontations ended in victory due to a technical point advantage within the full regulation time, i.e., 25 bouts. Out of the 30 observed bouts, 5 ended early with a decision for Full Ippon.

To illustrate the course of the bout, it was examined whether there are correlations between total fight time, break time, and effective fight time with the technical-tactical preparation indicators in the group of medalists from the Polish National Team. The study results indicate that total fight time is positively associated with Ea in PART I and negatively with Ae in PART II, III and Average Ae calculated across the three parts. On the other hand, break time was negatively related to the Average Ae, and effective fight time was negatively related to Ea in PART I and the Ae in PART I, III, and average Ae across the three parts (Table 3).

Table 3. Correlations between total fight time, break time, and effective fight time with technical-tactical indicators for medalists of the Polish National Team

Indicator	Total Time	Break Time	Effective Fight Time (total minus breaks)
Ea - PART I	r = 0.91	r = 0.60	r = 0.88
	p<0.001	p>0.05	**p<0.001**
Ea - PART II	r = 0.46	r = 0.56	r = 0.53
	p>0.05	p>0.05	p>0.05
Ea - PART III	r = - 0.47	r = - 0.53	r = - 0.56
	p>0.05	p>0.05	p>0.05
Average Ea	r = 0.44	r = 0.59	r = 0.60
	p>0.05	p>0.05	p>0.05
Ae - PART I	r = - 0.44	r = - 0.60	r = - 0.66
	p>0.05	p>0.05	**p<0.05**
Ae - PART II	r = - 0.65	r = - 0.61	r = - 0.59
	p<0.05	p>0.05	p>0.05
Ae - PART III	r = - 0.87	r = - 0.59	r = - 0.79
	p<0.001	p>0.05	**p<0.05**
Average Ae	r = - 0.93	- 0.89	r = - 0.83
	p<0.001	**p<0.001**	**p<0.001**
Aa - PART I	r = 0.49	r = 0.60	r = 0.60
	p>0.05	p>0.05	p>0.05
Aa - PART II	r = 0.52	r = 0.47	r = 0.56
	p>0.05	p>0.05	p>0.05
Aa - PART III	r = 0.10	r = 0.15	r = 0.05
	p>0.05	p>0.05	p>0.05
Average Aa	r = 0.53	r = 0.59	r = 0.53
	p>0.05	p>0.05	p>0.05

Ea I - effectiveness of the attack in the first part of the fight, Ea II - effectiveness of the attack in the second part of the fight., Ea III - effectiveness of the attack in the third part of the fight, Average Ea – Average effectiveness of the attack.

Ae I - efficiency of the attack in the first part of the fight, Ae II - efficiency of the attack in the second part of the fight, Ae III - efficiency of the attack in the third part of the fight, Average Ae – average efficiency of the attack.

Aa I - activity of the attack in the first part of the fight, Aa II - activity of the attack in the second part of the fight, Aa III - activity of the attack in the third part of the fight, Average Aa – average activity of the attack.

r - Spearman's Rank Correlation, p - level of significance, and statistically significant values are shown in bold.

The relationship between total fight time and Ea in PART I is positive and directly proportional. As total fight time increases, Ea also increases, with a correlation coefficient close to 1 (r=0.91). Conversely, the relationship between the average Ae across the three parts of the fight and total fight time is inversely proportional. As total fight time increases, the average Ae decreases (Table 3).

Before the fight, the average lactate level in the body was 2.89 mmol·L^{-1}, and it increased to 17.5 mmol·L^{-1} after the fight (Table 4). It was examined whether the lactate concentration level in the body before the fight significantly differed from its level after the fight. The study results indicate that the differences are statistically significant (p<0.001).

Table 4. Descriptive statistics of lactate concentration before and after the sports fight

Variables		Me	Min	Max	SD	$V_{\%}$	p
Lactate concentration - mmol·L^{-1} before the fight	2.89	2.9	2.5	3.5	0.31	10.75	
Lactate concentration - mmol·L^{-1} immediately after the fight	17.5	17.6	13	21.5	2.90	16.56	**<0.001**

- arithmetic mean, Me - median, Min - minimum value, Max - maximum value, SD - standard deviation, V%- coefficient of variation, p - level of significance, statistically significant values are shown in bold.

It was examined whether there is a relationship between the technical-tactical preparation indicators in different parts of the fight and blood lactate concentration. The relationship between lactate concentration and Ae in PART I is negative and inversely proportional. As lactate concentration increases, efficiency in Part I decreases. The correlation coefficient is -0.64 indicating a strong relationship. Lactate concentration accounts for 40.9% of the variation in Ae in PART I (coefficient of determination $r^2 = 0.4096$). If lactate concentration increases by 1 mmol·L^{-1}, Ae in PART I decreases by 2.22% (Table 5).

The relationship between lactate concentration and the average Ae across three parts is negative and inversely proportional (Table 5). As lactate concentration increases the average efficiency across the three parts decreases. The correlation coefficient is -0.71, indicating a significant relationship. Lactate concentration accounts for 50.4% of the variation in average Ae across the three parts (coefficient of determination $r^2 = 0.5041$). If lactate concentration increases by 1 mmol·L^{-1}, the average Ae across the three parts of the fight decreases by 4.66%.

The level of lactate concentration differed significantly before and after the fight for all the athletes examined. A statistically significant negatively relationship was demonstrated between lactate concentration and Ae in the first PART of the fight, as well as the overall attack efficiency of the athletes.

Table 5. Correlations between technical-tactical preparation indicators and lactate concentration (mmol·L^{-1}) after the fight

Indicator	Lactate concentration - mmol·L^{-1} immediately after the fight
Ea - PART I	r = - 0.34
	p>0.05
Ea - PART II	r = - 0.60
	p>0.05
Ea - PART III	r = - 0.50
	p>0.05
Average Ea	r = - 0.55
	p>0.05
Ae - PART I	r = - 0.64
	p<0.05
Ae - PART II	r = - 0.45
	p>0.05
Ae - PART III	r = - 0.59
	p>0.05
Average Ae	r = - 0.71
	p<0.05
Aa - PART I	r = 0.14
	p>0.05
Aa - PART II	r = 0.16
	p>0.05
Aa - PART III	r = - 0.17
	p>0.05
Average Aa	r = 0.15
	p>0.05

Ea I - effectiveness of the attack in the first part of the fight, Ea II - effectiveness of the attack in the second part of the fight., Ea III - effectiveness of the attack in the third part of the fight, Average Ea – Average effectiveness of the attack.

Ae I - efficiency of the attack in the first part of the fight, Ae II - efficiency of the attack in the second part of the fight, Ae III - efficiency of the attack in the third part of the fight, Average Ae – average efficiency of the attack.

Aa I - activity of the attack in the first part of the fight, Aa II - activity of the attack in the second part of the fight, Aa III - activity of the attack in the third part of the fight, Average Aa – average activity of the attack.

r - Spearman's Rank Correlation, p - level of significance, and statistically significant values are shown in bold.

Table 6 provides the basic descriptive statistics for heart rate measurements taken before and after the fight. It is worth noting that the heart rate level before the bout exceeded the normative values for this variable at rest. The table shows that the heart rate increases significantly after the fight, with the mean heart rate rising from 98.8 bpm before the fight to 170.4 bpm immediately after. The variation in heart rate also increases post-fight, as indicated by the higher standard deviation and coefficient of variation values. This data highlights the significant cardiovascular demand placed on athletes during a fight.

It was examined whether resting heart rate and heart rate immediately after the fight are related to technical-tactical preparation indicators. The analyses indicate

that Ea in PART II and averge Ea is related to heart rate immediately after the fight. The correlation coefficients were respectively -0.88; -0.82, indicating a very strong, negative, and inversely proportional relationship. As the heart rate immediately after the fight increases, Ea (PART II and Average) decreases (Table 7).

Table 6. Basic descriptive statistics of heart rate.

Variables	Me	Min	Max	SD	$V_{\%}$	p
Resting heart rate before the fight - bpm	98.8	98.5	94.0	103.0	2.78	2.81	**<0.001**
Heart rate immediately after the fight - bpm	170.4	169.0	160.0	186.0	8.83	5.18	

- arithmetic mean, Me - median, Min - minimum value, Max - maximum value, SD - standard deviation, V%- coefficient of variation, p - level of significance, statistically significant values are shown in bold.

Table 7. Correlations between technical-tactical preparation indicators and resting heart rate before the fight and immediately after the fight.

Indicator	Heart rate immediately after the fight - bpm
Ea - PART I	r = - 0.58
	p>0.05
Ea - PART II	r = - 0.88
	p<0.001
Ea - PART III	r = - 0.15
	p>0.05
Average Ea	r = - 0.82
	p<0.001
Ae - PART I	r = - 0.59
	p>0.05
Ae - PART II	r = - 0.47
	p>0.05
Ae - PART III	r = - 0.48
	p>0.05
Average Ae	r = - 0.60
	p>0.05
Aa - PART I	r = 0.15
	p>0.05
Aa - PART II	r = 0.33
	p>0.05
Aa - PART III	r= - 0.50
	p>0.05
Average Aa	r = 0.12
	p>0.05

Ea I - effectiveness of the attack in the first part of the fight, Ea II - effectiveness of the attack in the second part of the fight., Ea III - effectiveness of the attack in the third part of the fight, Average Ea – Average effectiveness of the attack.

Ae I - efficiency of the attack in the first part of the fight, Ae II - efficiency of the attack in the second part of the fight, Ae III - efficiency of the attack in the third part of the fight, Average Ae – average efficiency of the attack.

Aa I - activity of the attack in the first part of the fight, Aa II - activity of the attack in the second part of the fight, Aa III - activity of the attack in the third part of the fight, Average Aa – average activity of the attack.

r - Spearman's Rank Correlation, p - level of significance, and statistically significant values are shown in bold.

Discussion

The aim of the study was to assess the responses of selected physiological variables of the national team athletes during a top-level tournament and to diagnose the profile of their relationship with technical-tactical performance (activity, effectiveness, and efficiency indicators of attack).

To begin with, it is worth noting that, overall, the most favorable technical-tactical training indicators were achieved by the national team athletes in the first part of the bout (stand-up striking confrontation). A similar trend was observed across all tournament participants (all participating teams), with an interesting exception being a higher attack efficiency in the second part of the fight (stand-up grappling – throws and takedowns to the ground) [Ambrozy *et al.* 2023]. The efficiency indicator is a formula representing the overall ratio of successful attacks to all attempts x100. This illustrates a different specialization in the profile of scoring technical points (Polish national team vs. all championship participants).

In the author's own research, a relationship was observed between the duration of the fights and their effectiveness (especially visible in part 1 of the fight). The effectiveness indicator represents the ratio of successful attacks, classified according to technical scoring, to the total number of bouts fought by a given athlete. Discussed phenomenon could have resulted due to the fact that as the fights and tournament progresses, athletes strive to score points that can ensure victory or make up for the differences that arise during the fight to avoid losing. Previous studies confirm this approach to fighting in judo and ju-jitsu [Sterkowicz, Ambrozy 2001; Sterkowicz, Ambrozy 2003; Ambrozy 2008]. The longer the fights lasted in Part I, the more successful strikes and kicks, including those with higher scores, were performed by the participants. This highlights the importance of preparing the athlete for a full-length fight. The results also showed that prolonged fight duration significantly coincided with an increase in variables (Table 3), alongside a decrease in the athletes' efficiency. This was likely due to the increasing lactate buildup in the athletes' bodies, which could have caused fatigue [Slimani *et al.* 2017; Kons *et al.* 2020; Pavelka *et al.* 2020], leading to a downward trend in effective attacks.

The fight caused significant acidification of the subjects' bodies. The blood lactate concentration increased by 14.61 $mmol \cdot L^{-1}$ as a result of the continued fight, which is, for example, higher than the value recorded for kickboxing fights [Rydzik *et al.* 2021]. The total lactate concentration after the fight was 17.5 $mmol \cdot L^{-1}$, higher than the values recorded in boxing [Ghosh 2010], karate [Tabben *et al.* 2013] and taekwondo [Kim *et al.* 2014]. It should also be noted that such a high lactate concentration indicates significant acidification of the body fatigue after the bout [Amtmann *et al.* 2008; Gabrys *et al.* 2018].

The study also assessed the correlation profile between blood lactate concentration after the fight and

technical-tactical preparation indicators. The analysis results showed a negative relationship between attack efficiency and post-fight lactate concentration (significant in part I and in the average effectiveness - tab. 5). This indicates a significant involvement of anaerobic processes in ju-jitsu fighting, as they increase blood lactate concentration [Gorski 2019]. A detailed analysis of the results shows that the decrease in efficiency coincided with an increase in lactate concentration. In the studies by Rydzik *et al*., it was demonstrated that as the intensity of the bout increased, lactate concentration also increased, causing fatigue, which consequently lowered the athlete's performance [Rydzik *et al*. 2021]. It is therefore worth considering whether the physiological stress experienced by the athletes during Ju-Jitsu combat impairs their technical-tactical performance, or whether other mediating variables, such as the athlete's skill level, played a significant role in this. Amtman *et al*. [Amtmann *et al*. 2008] defined the role of lactate as an indicator of perceived physiological responses to exertion in mixed martial arts athletes. The researchers recorded a peak lactate concentration of 13 mmol·L^{-1} during MMA fights. Mixed martial arts, like ju-jitsu in the fighting variant, are very similar forms of competition. Therefore, the athletes in this analysis recorded higher lactate concentrations, which can be interpreted as greater physiological load. Similarly, Kirk *et al*. [2015] in their studies on measuring loads resulting from MMA fights using accelerometry, time-motion analysis, and lactate, defined training loads and innovative diagnostic methods.

Other authors determined the peak lactate concentration during judo fights [Obminski *et al*. 2010; Obminski *et al*. 2014]. Their study results show that judo athletes achieve higher lactate levels in the blood after longer fight durations. The lactate peak appeared earlier and its value was higher after longer durations. Abad *et al*. determined lactate concentration during Brazilian jiu-jitsu fights [Abad *et al*. 2016]. The authors demonstrated that Brazilian jiu-jitsu fights rely heavily on anaerobic metabolism. BJJ fights mainly take place on the ground, thus reflecting the third part of fighting in the fighting variant [Andreato *et al*. 2011]. An ideal reflection of combining the second and third parts of ju-jitsu fights is the Sambo fight. Coco et al. defined physiological responses during Sambo fights, where they recorded an average lactate level of 3.40 mmol·L^{-1} [Coco *et al*. 2022].

It is important to emphasize that immediately before the confrontation, the athletes' heart rate exceeded both the physiological norm and the average resting value measured outside of tournament conditions (71.5 bpm). The elevated heart rate was most likely a result of stress associated with anticipation of the bout, despite the physical inactivity of the participants. After the confrontation, the athletes experienced a significant increase in heart rate (before-fight heart rate 98.8 vs. post-fight heart rate 170.4), which is consistent with the conditions created by competition in combat sports [Slimani *et al*. 2018].

Another objective was to examine the relationship trend between heart rate immediately after the bout with technical-tactical preparation indicators. The analysis of attack effectiveness in Part II and average attack effectiveness in 3 parts, showed a significant correlation with heart rate immediately after the fight. The correlation coefficient of -0.88 and -0.82 (Table 7) indicates a very strong relationship between these variables. Importantly, this relationship is inversely proportional, meaning that an increase in heart rate immediately after the fight coincides with lower attack effectiveness in Part II and on average. Heart rate measured immediately after physical exertion is an important indicator of physical fitness [Slimani *et al*. 2018] and may be a significant variable affecting the athlete's technical-tactical preparation. A higher heart rate after the bout may indicate greater fatigue of the body [Gorski 2019] and a more difficult recovery to a state of readiness for subsequent attacks. It is also worth noting that the obtained results suggest there is potential to improve technical-tactical preparation through controlling [Ambrozy *et al*. 2021b] and optimizing heart rate after the bout. Targeted training to improve recovery processes may allow athletes to return to lower heart rate levels more quickly after the fight, which could lead to increased attack effectiveness. It is very important for tournament competition in ju-jitsu, where a competitor must fight between 3 to 5 matches to advance to the medal round.

Interestingly, no significant relationships were found between physiological variables and overall attack activity. This may suggest that a large portion of ineffective attacks serves as preparation for the actual attack and does not place as much strain on physiological variables. The athletes in the study, when performing these techniques, may not have been fully engaging their functional potential.

This work is part of a series focused on a multifaceted diagnosis of variables in a championship tournament [Ambrozy *et al*. 2023; Kedra *et al*. 2023; Ambrozy *et al*. 2024]. To the best of our knowledge, the presented study on the assessment and profile of the relationship between technical-tactical performance, lactate levels, and heart rate in the context of real sports combat during a top-level tournament, involving elite athletes, has not yet been presented, especially not with a personalized diagnosis for Ju-Jitsu fighters in the fighting formula. Although the results are promising, it is important to emphasize that this analysis requires further research to confirm the findings. It seems that the relationship between technical-tactical performance and physiological responses may also be determined by the (mediating) variable of technical and tactical skill level. In such a case, it is likely that an athlete with lower technical potential than their opponent will have to exert more effort during the con-

frontation, which will contribute to a higher increase in lactate levels and heart rate.

Limitations of the study

During the matches, consent was not obtained to conduct a broader spectrum of studies. This limitation resulted in the lack of a more detailed analysis of the athletes' heart rates and the measurement of parameters such as HR max or heart rate during the fight itself due to safety concerns. Moreover, HR parameters depend on climate (temperature and humidity) and other factors (genetic conditions, stress, and overtraining). Consequently, further research on physiological responses during, for example, simulated fights is necessary, where more variables can be controlled. Furthermore, a limitation of the study was the small sample size, although the participants belonged to the elite of this field. Future research should focus on larger samples, including both male and female athletes, and also aim to clarify potential cause-and-effect relationships.

Conclusions

Globally, the highest indicators of technical-tactical performance of the national team athletes were observed in the first stage of the bout (stand-up striking). The study revealed a significant positive relationship between the duration of the confrontation and attack effectiveness in the first part of the bout. However, prolonged fight duration was significantly associated with lower efficiency in the athletes. The fight induced significant activity in the physiological variables examined, evidenced by a significant increase in blood lactate levels and heart rate, which places high demands on the athletes in this regard. A comparative correspondence with other combat sports showed that these variables reach higher levels after Ju-Jitsu fights. The decrease in attack effectiveness was accompanied by increasing lactate levels, while the decrease in effectiveness in Part II and the average across all three parts of the fight was associated with an increase in heart rate.

Practical Application

Given the observed relationships, it is recommended to practice training that encompasses comprehensive development and refinement of all aspects of combat (stand-up striking, stand-up grappling, and groundwork), with an emphasis on preparing athletes for competition over the full duration of the match. The demonstrated variation in physiological variables (before and after the fight) and the profile of relationships suggest the need to develop training strategies aimed at increasing tolerance for technical-tactical functioning under conditions of elevated lactate levels and increased heart rate. It is also advisable to implement broadly individualized training to create a fighting model with a strategy that optimally balances sudden increases in heart rate and lactate levels with opportunities to find moments for rest during the bout (e.g., clinch, maintaining control on the ground), which can be supported by simulated, task-oriented sparring sessions. Finally, it is recommended to include strategies in training that optimize heart rate control after boutss to improve recovery processes and enhance athletes' performance in the later stages of the tournament.

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Conflict of Interest

The authors declare no conflict of interest.

Ethical considerations

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Bioethics Committee at the Regional Medical Chamber (No. 42/KBL/OIL/2015, dated April 15, 2015).

References

1. Abad C.C., McAnulty S.R., Barros M.P., Almeida A.L., Santos-Junior R.B., Smolarek A.C., Mascarenhas L.P., Souza T.P. (2016), *Lactate response to Brazilian Jiu-Jitsu matches across time*, "Journal of Exercise Physiology Online", vol. 19, no. 4, pp. 12-20.
2. Adam M., Smaruj M., Pujszo R. (2012), *Charakterystyka indywidualnego przygotowania techniczno-taktycznego zawodnikow judo, zwyciezcow Mistrzostw Swiata z Paryza w 2011 oraz z Tokio w 2010 roku,* "Ido Movement for Culture Journal of Martial Arts Anthropology", vol. 12, pp. 60-69.
3. Ambrozy T. (2008), *Struktura treningu ju-jitsu,* Biblioteka Trenera, Centralny Osrodek Sportu, Warsaw [in Polish].
4. Ambrozy T., Nowak M., Mucha D., Chwala W., Piwowarski J., Sieber L. (2014), *The influence of an original training programme on the general physical fitness of ju-jitsu trainees,* "Ido Movement for Culture Journal of Martial Arts Anthropology", vol. 14, no. 4, pp. 69-76; doi: 10.14589/ido.14.4.8.
5. Ambrozy T., Sterkowicz-Przybycien K., Sterkowicz S., Kedra A., Mucha D., Ozimek M., Mucha D. (2017), *Differentiation of Physical Fitness in Polish Elite Sports Ju-Jitsu Athletes Physical Fitness in Elite Ju-Jitsu Athletes*, "Journal of Kinesiology and Exercise Sciences", vol. 27, no. 79, pp. 57-70; doi: 10.5604/01.3001.0012.1430.
6. Ambrozy T., Rydzik L., Spieszny M., Chwala W.,

Jaszczur-Nowicki J., Jekielek M., Görner K., Ostrowski A., Cynarski W.J. (2021a), *Evaluation of the Level of Technical and Tactical Skills and Its Relationships with Aerobic Capacity and Special Fitness in Elite Ju-Jitsu Athletes*, "International Journal of Environmental Research and Public Health", vol. 18, no. 23, pp. 12286; doi: 10.3390/ijerph182312286.

7. Ambrozy T., Wasacz W., Koteja A., Zylka T., Stradomska J., Piwowarski J., Rydzik L. (2021b), *Special fitness level of combat sports athletes: mixed martial arts (MMA) and thai boxing (muay thai) in the aspect of training experience,* "Journal of Kinesiology and Exercise Sciences", vol. 31, no. 95, pp. 25-37; doi: 10.5604/01.3001.0015.7582.
8. Ambrozy T., Rydzik L., Wasacz W., Malodobry Z., Cynarski W.J., Ambrozy D., Kedra A. (2023), *Analysis of Combat in Sport JU-JITSU during the World Championships in Fighting Formula,* "Applied Sciences", vol. 13, no. 20, pp. 11417; doi: 10.3390/app132011417.
9. Ambrozy T., Rydzik L., Kasicki K., Malodobry Z., Kedra A. (2024). *Analysis of physical fitness, body composition, and structure of Polish national Ju-jitsu team members in relation to performance in competitions,* "Journal of Physical Education & Sport", vol. 24, no. 8, pp. 1953-1963; doi: 10.7752/jpes.2024.08217.
10. Amtmann J.A., Amtmann K.A., Spath W.K. (2008), *Lactate and Rate of Perceived Exertion Responses of Athletes Training for and Competing in a Mixed Martial Arts Event,* "The Journal of Strength & Conditioning Research", vol. 22, no. 2, pp. 645–647; doi: 10.1519/JSC.0b013e318166018e.
11. Andreato L.V., de Moraes S.F., de Moraes Gomes T.L., Esteves J.D.C., Andreato T.V., Franchini E. (2011), *Estimated aerobic power, muscular strength and flexibility in elite Brazilian Jiu-Jitsu athletes*, "Science & Sports", vol. 26, no. 6, pp. 329-337; doi: 10.1016/j.scispo.2010.12.015.
12. Bocioaca L. (2014), *Technical and Tactical Optimization Factors in Judo,* "Procedia-Social and Behavioral Sciences", vol. 117, pp. 389–394; doi: 10.1016/j.sbspro.2014.02.233.
13. Chandel N.S. (2021), *Glycolysis*, "Cold Spring Harbor Perspectives in Biology", vol. 13, pp. a040535; doi: 10.1101/cshperspect.a040535.
14. Chapelot D., Charlot K. (2019), *Physiology of energy homeostasis: Models, actors, challenges and the glucoadipostatic loop,* "Metabolism" vol. 92, pp. 11-25; doi: 10.1016/j.metabol.2018.11.012.
15. Coco M., Perciavalle V., Cavallari P., Perciavalle V. (2016), *Effects of an Exhaustive Exercise on Motor Skill Learning and on the Excitability of Primary Motor Cortex and Supplementary Motor Area,* "Medicine", vol. 95, no. 11, pp. e2978; doi: 10.1097/MD.0000000000002978.
16. Coco M., Platania S., Castellano S., Sagone E., Ramaci T., Petralia M.C., Agati M., Massimino S., Di Corrado D., Guarnera M., Pirrone C., Costa C., De Pasquale C., Perciavalle V., Cavallari P., Di Nuovo S., Di Gregorio G., Perciavalle V., Buscemi A. (2018), *Memory, personality and blood lactate during a judo competition,* "Sport Sciences for Health", vol. 14, pp. 547-553; doi: 10.1007/s11332-018-0458-x.
17. Coco M., Di Corrado D., Ramaci T., Di Nuovo S., Perciavalle V., Puglisi A., Cavallari P., Bellomo M., Buscemi A. (2019), *Role of lactic acid on cognitive functions,* "The Physician and Sports Medicine", vol. 47, no. 3, pp. 329-335; doi: 10.1080/00913847.2018.1557025.
18. Coco M., Buscemi A., Tušak M., Perciavalle V., Nifosì A., Cavallari P., Di Corrado D., Perciavalle V. (2022), *Attentive Processes and Blood Lactate in the Sambo,* "International Journal of Environmental Research and Public Health", vol. 19, no. 3, pp. 1113; doi: 10.3390ijerph19031113.
19. Gabrys T.T., Stanula A., Szmatlan-Gabrys U. (2018), *A comparison of methods for calculating lactate anaerobic thresholds in judo and mixed martial arts athletes,* "In SOCIETY, INTEGRATION, EDUCATION, Proceedings of the International Scientific Conference", vol. 4, pp. 35-45; doi: 10.17770/sie2018vol1.3183.
20. Ghosh A.K. (2010), *Heart rate, oxygen consumption and blood lactate responses during specific training in amateur boxing,* "International Journal of Applied Sports Sciences", vol. 22, no. 1, pp. 1-12.
21. Gorski J. [ed.] (2019), *Fizjologia wysilku i treningu fizycznego,* PZWL Wydawnictwo Lekarskie, Warsaw, pp. 28, 74, 148 [in Polish].
22. Halson S.L. (2014), *Monitoring Training Load to Understand Fatigue in Athletes,* "Sports Medicine", vol. 44, no. 2, pp. 139–147; doi: 10.1007/s40279-014-0253-z.
23. Ju-Jitsu International Federation – JJIF. (2023), *Ju-Jitsu Fighting Rule Book, JJIFSport–Ju-Jitsu Int Fed no date Rules_JJIF-Fighting-2023,* Available online: https://jjif.sport/wp-content/uploads/2021/05/Rules_JiuJitsu-2020-AE.pdf, (access August 27, 2023).
24. Kachenkova E., Zavalishina S., Kartashev V. (2023), *The use of the multicomplex sports nutrition "MDX" in martial arts athletes,* "In E3S Web Conferences, EDP Sciences", vol. 460, pp. 11007; doi: 10.1051/e3sconf/202346011007.
25. Kedra A., Kasicki K., Ambrozy T. (2023), *Analysis of physical fitness level and its relationship with the level of Technical-Tactical Preparedness of Ju-Jitsu Athletes,* "Archives of Tourism, Hospitality and Sport Science", vol. 1, pp. 39-47; doi: 10.5604/01.3001.0054.2846.
26. Kim D.Y., Seo B.D., Choi P.A. (2014), *Influence of taekwondo as security martial arts training on anaerobic threshold, cardiorespiratory fitness, and blood lactate recovery,* "Journal of Physical Therapy Science", vol. 26, no. 4, pp. 471–474; doi: 10.1589/jpts.26.471.
27. Kirk C., Hurst H.T., Atkins S. (2015), *Measuring the Workload of Mixed Martial Arts using Accelerometry, Time Motion Analysis and Lactate*, "International Journal of Performance Analysis in Sport", vol. 15, no. 1, pp. 359–370; doi: 10.1080/24748668.2015.11868798.
28. Kons R.L., Orssatto L.B.R., Detanico D. (2020), *Acute performance responses during repeated matches in combat sports: A systematic review,* "Journal of Science and Medicine in Sport", vol. 23, no. 5, pp. 512–518; doi: 10.1016/j.jsams.2019.12.004.
29. Moscatelli F., Valenzano A., Petito A., Triggiani A.I., Ciliberti M.A.P., Luongo L., Carotenuto M., Esposito M.,

Messina A., Monda, V., Monda M., Capranica L., Messina G., Cibelli G. (2016), *Relationship between blood lactate and cortical excitability between taekwondo athletes and non-athletes after hand-grip exercise,* "Somatosensory & Motor Research", vol. 33, no. 2, pp. 137-144; doi: 10.1080/08990220.2016.1203305.

30. Nirody J.A., Budin I., Rangamani P. (2020), *ATP synthase: Evolution, energetics, and membrane interactions,* "Journal of General Physiology", vol. 152, no. 11, pp. E201912475; doi: 10.1085/jgp.201912475.
31. Obminski Z., Lerczak K., Witek K., Pintera M. (2010), *Introduction Studies on lactate peak in blood following judo match,* "Journal of Combat Sport and Martial Arts", vol. 1, pp. 95–99.
32. Obminski Z., Witek K., Lerczak K., Borkowski L., Szczepanska B., Blach W. (2014), *Work-to-rest ration during three repeated judo struggles separated by short intermissions. A preliminary study,* "Journal of Combat Sport and Martial Arts", vol. 5, pp. 53–56; doi: 10.5604/20815735.1141782.
33. Pavelka R., Trebicky V., Trebicka Fialova J., Zdobinsky A., Coufalova K., Havlícek J., Tufano J.J. (2020), *Acute fatigue affects reaction times and reaction consistency in Mixed Martial Arts fighters,* "PLoS One", vol. 15, no. 1, pp. e0227675; doi: 10.1371/journal.pone.0227675.
34. Poliszczuk D. (2002), *Dzialanie startowe zawodnikow jako czynnik indywidualizacji procesu treningu,* "Wychowanie Fizyczne i Sport", vol. 46, pp. 110–111 [in Polish].
35. Ronikier A. (2001), *Fizjologia sportu,* Biblioteka Trenera COS, Warsaw [in Polish].
36. Rydzik L., Ambrozy T. (2021), *Physical fitness and the level of technical and tactical training of kickboxers,* "International Journal of Environmental Research and Public Health", vol. 18, no. 6, pp. 3088; doi: 10.3390/ijerph18063088.
37. Rydzik L., Maciejczyk M., Czarny W., Kedra A., Ambrozy T. (2021), *Physiological Responses and Bout Analysis in Elite Kickboxers During International K1 Competitions,* "Frontiers in Physiology", vol. 12, pp. 691028; doi: 10.3389/fphys.2021.691028.
38. Rydzik L., Mardyla M., Obminski Z., Wiecek M., Maciejczyk M., Czarny W., Jaszczur-Nowicki J., Ambrozy T. (2022), *Acid–Base Balance, Blood Gases Saturation, and Technical Tactical Skills in Kickboxing Bouts According to K1 Rules,* "Biology", vol. 11, no. 1, pp. 65; doi: 10.3390/biology11010065.
39. Slimani M., Davis P., Franchini E., Moalla W. (2017), *Rating of perceived exertion for quantification of training and combat loads during combat sport-specific activities: a short review,* "The Journal of Strength & Conditioning Research", vol. 31, no. 10, pp. 2889-2902.
40. Slimani M., Znazen H., Sellami M., Davis P. (2018), *Heart rate monitoring during combat sports matches: a brief review*. "International Journal of Performance Analysis in Sport", vol. 18, no. 2, pp. 273–292; doi: 10.1080/24748668.2018.1469080.
41. Sozanski H. (1999), *Podstawy teorii treningu sportowego,* Biblioteka Trenera COS, Warsaw [in Polish].
42. Sterkowicz S. (1998), *Ju-jitsu: wybrane aspekty sztuki walki obronnej,* Studia i Monografie, Akademia Wychowania Fizycznego, Krakow [in Polish].
43. Sterkowicz S., Maslej P. (1999), *Analiza przebiegu walki judo na podstawie jej struktury czasowej - badania porownawcze,* "Sport Wyczynowy", vol. 37, no. 7-8; pp. 33-37 [in Polish].
44. Sterkowicz S., Ambrozy T. (2001), *Struktura walki sportowej ju-jitsu* [in:] *Czynnosci zawodowe trenera i problemy badawcze w sportach walki,* Zeszyty Naukowe AWF Krakow, Krakow, pp. 187–200 [in Polish].
45. Sterkowicz S., Ambrozy T. (2003), *Ju-jitsu sportowe: proces szkolenia (podrecznik trenera),* Europan Association for Security, Krakow [in Polish].
46. Tabben M., Sioud R., Haddad M., Franchini E., Chaouachi A., Coquart J., Chaabane H., Chamari K., Tourny-Chollet C. (2013) *Physiological and Perceived Exertion Responses during International Karate Kumite Competition,* "Asian journal of sports medicine", vol. 4, no. 4, pp. 263-271; doi: 10.5812/asjsm.34246.

Ocena odpowiedzi fizjologicznych i ich relacja z wydajnością techniczno-taktyczną wśród zawodników kadry Polski podczas mistrzostw świata ju-jitsu formuły *fighting*

Słowa kluczowe: stężenie kwasu mlekowego, tętno, wskaźniki techniczno-taktyczne, sporty walki, ju-jitsu

Streszczenie

Tło. Konfrontacja w sportowym ju-jitsu, w formule *fighting*, charakteryzuje się zmiennym wysiłkiem, pracą acykliczną i częstymi zmianami warunków walki, co ma wszechstronny wpływ na organizm sportowca, wywołując kaskadę procesów fizjologicznych. Celem badania była ocena poziomu i identyfikacja charakteru zależności między wybranymi zmiennymi fizjologicznymi a wydajnością techniczno-taktyczną podczas turnieju mistrzowskiego na wysokim poziomie, wśród członków polskiej reprezentacji w ju-jitsu.

Materiał i metoda. W badaniu wzięło udział 10 zawodników ju-jitsu, członków kadry narodowej (wiek: 27.7 ± 4.1 lat; wzrost: 181.2 ± 7.8 cm; masa ciała: 82.8 ± 8.6 kg; staż treningowy: 18.8 ± 4.5 lat). Podczas Mistrzostw Świata Seniorów w Ju-Jitsu 2016 dokonano pomiarów stężenia kwasu mlekowego i tętna przed oraz po walce sportowej. Walki turniejowe były nagrywane za pomocą specjalistycznych kamer, a następnie, na podstawie retrospektywnej analizy, obliczono i oceniono wskaźniki techniczno-taktyczne (dla trzech części walki) pod kątem zależności z zarejestrowanymi zmiennymi fizjologicznymi. Poziom istotności statystycznej ustalono na $p < 0.05$.

Wyniki. W trakcie analiz wykazano istotne różnice ($p < 0.001$) przed i po walce w poziomach stężenia kwasu mlekowego (2.89±0.31 vs. 17.5±2.9 mmol·L^{-1}) oraz zmiennych tętna (98.8±2.78 vs. 170.4±8.83 bpm). Dodatkowo, stwierdzono istotne, silne i negatywne korelacje między wydajnością techniczno-taktyczną a stężeniem kwasu mlekowego dla zmiennej efektywności ataku w części I walki (Ae część I: $r = -0.64$; $p <$

0.05) oraz średniej efektywności z trzech części walki (Średnia Ae: $r = -0.71$; $p < 0.05$). Podobny charakter zależności wykazano przy porównaniu zmiennych tętna z wydajnością techniczno-taktyczną, gdzie stwierdzono istotne, silne i negatywne korelacje dla skuteczności ataku w części II walki (Ea część II: $r = -0.88$; $p < 0.001$) oraz średniej skuteczności ataku z części I, II i III walki (Średnia Ea: $r = -0.82$; $p < 0.001$).
Wnioski. Walka wywołała znaczną aktywność w badanych zmiennych fizjologicznych (tętno i poziom mleczanu). Spadek skuteczności ataku wiązał się ze wzrostem poziomu mleczanu, podczas gdy spadek skuteczności w części II i średnia we wszystkich trzech częściach walki wiązała się ze wzrostem tętna. Ze względu na turniejowy charakter dyscypliny zaleca się zintensyfikowanie programów treningowych obejmujących kontrolę tętna po walce w celu usprawnienia procesu regeneracji powysiłkowej i optymalizacji efektywności w późniejszych fazach turnieju. Ponadto zaleca się działania mające na celu zwiększenie tolerancji na funkcjonowanie w warunkach zakwaszenia organizmu i podwyższonego tętna.