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EFFECTS OF ORIGINAL PHYSICAL TRAINING PROGRAM ON CHANGES IN BODY COMPOSITION, UPPER LIMB PEAK POWER AND AEROBIC PERFORMANCE OF A MIXED MARTIAL ARTS FIGHTER

Łukasz Tota[1(ABDE)], Tomasz Drwal[2(AB)], Marcin Maciejczyk[1(ADEF)], Zbigniew Szyguła[1(BF)], Wanda Pilch[1(DE)], Tomasz Pałka[1(AB)], Grzegorz Lech[3(E)]

[1]Institute of Biomedical Sciences, University School of Physical Education, Krakow, Poland
[2]MMA Fighter, Ultimate Fighting Championship, Pro MMA Challange
[3]Institute of Sport, University School of Physical Education, Krakow, Poland

Abstract

Objective: To evaluate the effect of the original 11-week physical training program on the body composition, upper limb power and aerobic performance of a mixed martial arts (MMA) fighter.

Methods: The study was carried out on an MMA middle-weight fighter. Before and after the workout which was specifically designed for this sport, body composition was assessed using bioelectrical impedance. Further evaluated were peak power (PP) of the upper limbs (Wingate Test for upper limbs) and aerobic performance (treadmill graded test). In the graded test, maximal oxygen consumption ($\dot{V}O_2max$) and the second ventilatory threshold (VT2) were determined. The utilized training methods were analyzed according to type of physical training preparation (comprehensive, targeted and special) due to their intensity and energy system (aerobic, anaerobic, mixed).

Results: After completing the training program, fat mass decreased in the fighter by 1.4 kg, while lean body mass increased by 1.5 kg. Improvement was noted in PP (7.8 vs. 8,1 $W \cdot kg^{-1}$) and $\dot{V}O_2max$ (57.1 vs. 58.4 $ml \cdot kg^{-1}$). Starting speed and speed endurance improved as well: time of PP attainment reduced by 0.91 seconds, while the time of maintaining PP was extended by 1 second.

Conclusions: The developed and implemented physical training program resulted in beneficial changes in the fighter's body composition. After the training period, an improvement in peak power of the upper limbs, aerobic performance and effectiveness of lactate elimination from the blood were noted. Physiological measurements have confirmed the effectiveness of applied training method.

***Key words**: peak power, maximal oxygen consumption, mixed martial arts, physical training*

Introduction

An increase in the popularity of mixed martial arts (MMA) in recent years has caused a growing interest in issues related to its training process, as well as control of physical preparation of representatives of this sport. Mixed martial arts are characterized by a variety of techniques typical of an array of various combat sports (among others: boxing, wrestling, karate, judo, kickboxing, jiu-jitsu), and the course of the fight itself, is characterized by varying degrees of intensity and changes in fighting conditions. Despite the growing popularity of the sport, there is little research exemplifying the physiological profile of MMA fighters. To our knowledge, only three studies [1-3] attempted to describe the physiological profile of an MMA fighter and the construction of his body. The authors of these studies have shown that the physiological profile of an MMA fighter is similar to competitors training judo and wrestling [1]. The studied MMA fighters were also characterized by high aerobic endurance performance, however, their anaerobic performance was comparable to the level of representatives of other combat sports [2]. At the same time, MMA fighters have lower body fatness than traditional martial arts fighters [3]. An MMA fight usually consists of three 5-minute rounds with a 1-minute break [2], and in the course of combat, the fighter performs dynamic moves of a quick and forceful nature. Thus, an MMA fighter must have high aerobic as well as anaerobic potential (phosphagenic and glycolytic energy system) both of the upper and lower limbs [2,4,5].

The fundamental problem of mixed martial arts is its lack of a unified athlete training system, as well as a rational long-term training plan. For this reason, it is necessary to develop methods of training specific to MMA in order to optimally prepare the fighter for sports combat. Few scientific studies have shown [2,4,6] that training programs implemented by athletes do not always lead to improved aerobic and anaerobic fitness indicators. Amtmann [6] clearly indicates that MMA fighters are in need of adequate instructions and proper training conducted by an experienced specialist, as the training sessions implemented by them are not adequately balanced in relation to the requirements of the sport. In planning MMA training, as in other combat sports, improvement of technical and tactical training should be taken into consideration, as well as the development of muscle strength and power, speed and endurance. For this reason, it is necessary to develop methods of training specific to MMA in order to optimally prepare the fighter for fights. The aim of the study was to evaluate the effects of the original 11-week training program on body composition, upper limb power and aerobic performance of an MMA fighter.

Methods

The study was conducted in accordance with the Declaration of Helsinki International Ethical Guidelines for *Biomedical Research Involving Human Subjects*. The fighter was informed about the purpose and course of study, and submitted written consent to participate in the research. The fighter submitted a valid note stating that he had undergone sports-medical examination, which was the condition for accession to the stress test. Stress tests were carried out under the supervision of a sports medicine physician.

Stress tests and anthropometric measurements were taken at the beginning and end of the fight preparatory period, which was contracted for three, 5-minute rounds. The period of preparation for the fight lasted 11 weeks.

The fighter performed two stress tests in each study series: the Wingate Test for upper limbs (peak power of the upper limbs) and the graded test until volitional exhaustion (measurement of maximal minute oxygen consumption and appointment of the second ventilatory threshold). The tests were carried out with a 1-day break, and the first to be performed was the Wingate Test. Furthermore, before and after the graded test, the level of lactate concentration was measured. During the 11-week training period, the applied training measures were registered.

Subject profile

The study was carried out on the first Polish player Mixed Martial Arts to fight in the American Ultimate Fighting Championship organization. Currently, the player belongs to the Pro Challenge MMA fighting organization in middleweight category. The winner of 21 fights, including 12 by knockout, 6 by submission, three by the judges' decision. Before the training program, the fighter's body height was 178 cm, body mass 88.8 kg, and body fat mass 13.2 kg.

Anthropometric measurements

The anthropometric measurements assessed body height (BH), body mass (BM), fat mass (FM) and lean body mass (LBM). Body mass and composition were determined using the Jawon Medical, IOI model 353 (Korea) bioimpedance body composition analyzer, and body height was measured using the Martin (USA) type anthropometer with 1 mm accuracy.

Graded test

The $\dot{V}O_2$max and the second ventilatory threshold (VT2) were established in the test, which was performed on a motorized treadmill (Saturn 250/100R, h/p/Cosmos, Germany). The exercise began with a 4-minute warm-up performed at the speed of 8 $km \cdot h^{-1}$ km and a 1° inclination. Next, the running speed was increased by 1,0 $km \cdot h^{-1}$ every 2 minutes. When the heart rate became close to the maximal rate, the speed was maintained and the load was increased by enlarging (every minute) the inclination of the treadmill by 1°. The test was performed until the fighter's refusal to continue because of extreme fatigue.

The following indicators were registered by the ergospriometer (919 Medikro, Finland) during the test: pulmonary ventilation, percentage of carbon dioxide in exhaled air, minute oxygen uptake, minute production of carbon dioxide, respiratory quotient, and the respiratory equivalent for carbon dioxide. Heart rate (HR) was measured by a pulsometer (S- 610i, Polar, Finland).

In order to determine VT2, changes in respiratory indicators with increasing intensity were analyzed. VT2 designation criteria were as follows: a) the percentage of CO_2 in the exhaled air reached the maximum value, and then reduced, b) the respiratory equivalent ratio of carbon dioxide obtained a minimum value and began to increase, c) after exceeding VT2, a nonlinear increase in pulmonary ventilation was noticed [7,8]. The highest recorded value of $\dot{V}O_2$ was considered as $\dot{V}O_2$max.

Based on the results of the first graded test, three training zones in which running training of the fighter was organized were determined: below the second ventilatory threshold (sub-threshold zone), above this threshold (above-threshold zone) and near-threshold zone (HR_{VT2}±3 $beats \cdot min^{-1}$).

Biochemical analysis

Blood for biochemical tests was taken from the fingertip before the graded test as well as 3 and 20 minutes after its completion. The plasma obtained after centrifugation of the whole blood lactate concentration was determined (La^-) by colorimetric enzymatic assay (Lactate PAP, BioMerieux) using a spectrophotometer (Spekol 11, Carl Zeiss Jena, Germany).

Wingate Test for upper limbs

The purpose of the test was to measure the peak power of the upper limbs. The Wingate Test, 20-second version [9], was performed with a 4.5% load of body mass. Prior to the test, the subject performed a 5-minute warm-up on a cycle-ergometer with a load of 1.5 kg, the tempo during the warm-up was 60 rpm. After the second and forth minute of the warm-up, the subject performed two 3-second maximal accelerations and then returned to the tempo of 60 rev/min. The main test was performed two minutes after the warm-up. The aim of the subject was to obtain maximum pedaling tempo and maintain it as long as possible. The test was performed on a specially adapted ergometer (Monark 834E, Sweden) equipped with a device measuring the duration of each rotation and connected to a computer. The ergometer was placed on a special stand in such a manner that the axis of bottom bracket was at the height of the subject's shoulders, who was in a sitting position. The ergometer pedals were replaced with handles for the upper limbs. The distance between the chest and the handles were set so that the elbow was in slight deflection during maximum range. For the time of the test, the subject's trunk was stabilized. The software (MCE, JBA, Poland) allowed to measure the following indicators: mean power (MP), total work (TW), peak power (PP), time of attaining peak power (TOPP) and the time of maintaining peak power (TMPP).

Characteristics of implemented training session

Training load analysis was performed on the basis of the logs registered by the subject and coach. The intensity of each workout was monitored using a heart rate monitor (Suunto Ambit). The training load was determined by the method of training load registration, taking measures applied in martial arts into account [10-13]. In the present study, data on the characteristics of the different training loads is listed as totals in separate 7-day micro-cycles, during which twelve training session occurred (Table 1). The characteristics of the intensity range were applied utilizing Sozański and Śledziewski's proposal [11], and Laskowski's [13] with our own modifications, which are shown in Table 2. Individual training measures were divided according to: a) type of preparation (information area), b) exercise type: comprehensive, targeted and special, c) work intensity (energy system). A detailed presentation of the implemented training is shown in Tables 3, 4 and 5.

Table 1. *General diagram of micro-cycle structure*

Day						
Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Training session 1	Training session 1	Biological renewal	Training session 1	Training session 1	Biological renewal	Free
Training session 2	Training session 2		Training session 2	Training session 2		
Training session 3	Training session 3		Training session 3	Training session 3		

Table 2. *Characteristics of intensity ranges in the registration of training loads*

Range of intensity	Energy system	Percentage of maximal potential	Duration (min:s)
1	aerobic	> 80	3:00 <
2	aerobic – anaerobic	81–90	1:30 – 2:59
3	anaerobic – lactic	91–100	0,11 – 1:29
4	anaerobic – alactic		< 0,10

Table 3. *Analysis of fighter's completed training loads – information area*

Information area \ Micro-cycle		1	2	3	4	5	6	7	8	9	10	11
Comprehensive	[min]	200	250	250	300	200	550	200	180	200	150	100
	[%]	71,4	72,5	78,1	75,0	83,3	78,6	83,3	58,1	50,0	50,0	35,7
Targeted	[min]	70	80	60	60	30	120	20	30	100	50	30
	[%]	25,0	23,2	18,8	15,0	12,5	17,1	8,3	9,7	25,0	16,7	10,7
Special	[min]	10	15	20	40	10	30	20	100	100	100	150
	[%]	3,6	4,3	6,3	10,0	4,2	4,3	8,3	32,3	25,0	33,3	53,6
Total [min]		280	345	320	400	240	700	240	310	400	300	280

Table 4. *Analysis of fighter's implemented training loads – energy area*

Energy system \ Micro-cycle		1	2	3	4	5	6	7	8	9	10	11
Aerobic	[km]	220	300	300	300	200	500	180	150	200	140	80
	[%]	78,6	87,0	88,2	75,0	83,3	71,4	75,0	48,4	50,0	46,7	28,6
Aerobic – anaerobic	[km]	40	20	25	50	20	150	20	100	100	100	120
	[%]	14,3	5,8	7,4	12,5	8,3	21,4	8,3	32,3	25,0	33,3	42,9
Anaerobic lactic	[km]	15	20	10	30	5	30	20	30	60	30	40
	[%]	5,4	5,8	2,9	7,5	2,1	4,3	8,3	9,7	15,0	10,0	14,3
Anaerobic alactic	[km]	5	5	5	20	15	20	20	30	40	30	40
	[%]	1,8	1,4	1,5	5,0	6,3	2,9	8,3	9,7	10,0	10,0	14,3

Table 5: *Analysis of fighter's completed running training load*

Intensity \ Micro-cycle		1	2	3	4	5	6	7	8	9	10	11	Total [km]
Below-threshold	[km]	50	55	50	40	10	41	5	10	10	10	10	291
	[%]	62,5	84,6	50,0	55,6	22,2	50,6	13,2	18,2	28,6	22,2	19,2	
Near-threshold	[km]	25	10	40	27	30	15	25	20	15	15	20	242
	[%]	31,3	15,4	40,0	37,5	66,7	18,5	65,8	36,4	42,9	33,3	38,5	
Above-threshold	[km]	5	0	10	5	5	25	8	25	10	20	22	133
	[%]	6,3	0,0	10,0	6,9	11,1	30,9	21,1	45,5	28,6	44,4	42,3	
Total [km]		80	65	100	72	45	81	38	55	35	45	52	668

Results

Realization of the training program favorably influenced both the changes in body composition as well as the fighter's exercise performance. When maintaining a constant body mass, the sessions increased lean body mass by 1.5 kg (up to 77.1 kg) and decreased fat mass in the body by 1.4 kg (up to 11.8 kg). After a period of preparation, the graded test allowed to observe prolongation of the running time and at the same time, the fighter completed the test at a higher speed. The level of $\dot{V}O_2max$ improved, and the intensity of work when exceeding VT2 increased from 73.7% to 85.9% $\dot{V}O_2max$. After completing the training program, higher lactate concentration after the test (3 min) was reported prior to the graded test (before training: 9.99 mmol·L^{-1}, after 12.96 mmol·L^{-1}) as well as an improvement in lactate elimination tempo (ΔLa before the workout 4.63 mmol·L^{-1}, after 5.61 mmol·L^{-1}). After training, the values of the peak power of the upper limbs relative to body mass were increased. Time of attaining PP shortened and the time of maintaining PP extended. Detailed changes in physiological parameters under the influence of training are shown in Table 6.

Table 6. *Level of selected indicators characterizing the anaerobic and aerobic performance*

			before	after
MP	[W]		619	630
	[W·kg^{-1}]		6.9	7.1
TW	[kJ]		12.27	13.30
PP	[W]		692	720
	[W·kg^{-1}]		7.79	8.10
TOPP	[s]		4.91	4.00
TMPP	[s]		5.80	6.80
t	(min)	VT2	16.00	18.00
		max	22.00	23.00
v	(km·h^{-1})	VT2	14.0+1^0	15.0+1^0
		max	15.0+4^0	16.0+4^0
HR	(b·min^{-1})	VT2	164	168
		max	182	182
VO_2	(L·min^{-1})	VT2	3.74	4.47
		max	5.07	5.20
VO_2	(mL·min^{-1}·kg^{-1})	VT2	42.1	50.2
		max	57.1	58.4
%HRmax VT2	(%)		90	92
%$\dot{V}O_2$max VT2	(%)		73.7	85.9
Distance covered	[m]		4136	4707
La_0	(mmol·L^{-1})		1.23	1.65
La_3	(mmol·L^{-1})		9.99	12.96
La_{20}	(mmol·L^{-1})		5.36	7.35
Δ La	(mmol·L^{-1})		4.63	5.61

before, after - laboratory tests performed before and immediately after the original 11-week physical training program, MP – mean power [W, W·kg^{-1}]; TW - total work [kJ]; PP - peak power [W, W·kg^{-1}]; TOPP – time of attaining peak power [s]; TMPP - time of maintaining peak power [s], t - time in the graded test, HR - heart rate; $\dot{V}O_2$ – maximal minute oxygen consumption (L·min^{-1}) and relative to body mass (mL·min^{-1}·kg^{-1}), La – blood lactate: 0 - output, 3' - in the third minute, after completion of the graded test, 20' in the twentieth minute after the test, Δ - difference La_3- La_{20}), VT2 - second ventilatory threshold

Discussion

In available literature, there are no studies on the analysis of training loads or assessment of the effects of their implementation in athletes training MMA. In the present study, for the first time, changes in aerobic or anaerobic performance of a fighter specializing in mixed martial arts was evaluated using the original tailored sports training program. The purpose of the observations was to determine the effectiveness of the developed physical training program specific for MMA on body composition, upper limb peak power and the level of indicators characterizing aerobic endurance performance ($\dot{V}O_2$max, VT2).

A characteristic feature of the training program was increasing the inclusion of running training, implemented as separate training units. During the training period, workouts of near- and above-threshold intensity dominated in the final weeks of the preparation period. The largest volume of running training carried out at below-threshold intensity occurred during the initial period of observation. The time devoted to special exercise while reducing the share of comprehensive training preparation was also extended. The initial preparatory period was dominated by aerobic exercises. In subsequent weeks, the amount of mixed-energy exercises was increased. At the end of the preparatory period, inclusion of lactic as well as alactic anaerobic training efforts was increased. In periodization of the training process for the studied fighter, at the final stage of preparation, the time devoted to special exercises involving anaerobic metabillism while reducing the share of comprehensive preparation training was extended. As a result, the implemented training was effective: an improvement in upper limb peak power was noted and the levels of $\dot{V}O_2$max and VT2 increased. The fighter also started to tolerate higher lactate concentrations and the tempo of the lactate removal rate improved.

Prior to training, the studied middle-weight fighter's percentage of body fat was 14.9%, and after training it was reduced to 13.2%. In their study, Marinho et al. [14] attempted to determine the anthropometric profile of a mixed martial arts fighter. The average body mass of the fighters totaled 82.1 ± 10.9 kg, while the fat content was 11.87 ± 5.11%. Nonetheless, the authors drew attention to the need to reduce body fat. These data indicate that the fighter studied in our research should continue the training program in order to further reduce adipose tissue. Franchini [15] showed that high levels of body fat negatively affect sport performance of fighters training sports which have relevance to the locomotion of the athlete. For the studied fighter, an increase in lean body mass while maintaining a constant total body mass was also observed. Maciejczyk et al. [16] demonstrated that an increase in total body mass resulting from an increase in lean body mass may also adversely affect endurance performance of the organism.

In the sports practice, Wingate Test results are most commonly used for assessment, but also for conducting comparisons of fighters' anaerobic potential. High anaerobic performance in athletes training martial arts influences the effectiveness of offensive as well as defensive actions [17]. Published scientific studies conducted on martial arts fighters show the expediency of conducting the Wingate Test on the lower limbs [18]. Taking into account the specificity of mixed martial arts sports, it is advisable to carry out measurements of anaerobic power of the upper limbs. For the studied fighter, the peak anaerobic power obtained during the Wingate Test performed on the upper limbs amounted to 7.8 $W \cdot kg^{-1}$ in the first, and 8.1 $W \cdot kg^{-1}$ in the second series of tests. Similar results were obtained by Polish fighters belonging to the national team: 8.0 ± 0.9 $W \cdot kg^{-1}$; better results were obtained by Greco-Italian wrestlers 9.7 ± 1.0 $W \cdot kg^{-1}$ [19].

Due to the specific nature of competition in this discipline, the body of the fighter should have the ability to function in conditions of severe disturbances of homeostasis, manifested, among others, in high levels of post-workout lactate concentration and post-exercise rapid elimination ability, which facilitates a high level of aerobic potential [17]. Improvement in the fighter's $\dot{V}O_2$max under the influence of the implemented training program was noted, and its level after the workout was over 58 $mL \cdot kg^{-1} \cdot min^{-1}$, which shows aerobic preparation of the fighter comparable to data presented by other MMA fighters (55.5-60 $mL \cdot kg^{-1} \cdot min^{-1}$) [1,2]. In other similar sports disciplines, the average maximal oxygen consumption stands at 40.8 $mL \cdot kg^{-1} \cdot min^{-1}$ (judokas) [18], 53.8 $mL \cdot kg^{-1} \cdot min^{-1}$ (judokas) [20], and 63,8 ± 4,8 $mL \cdot kg^{-1} \cdot min^{-1}$ (boxers) [21].

MMA fighters should have a high lactate tolerance, a large buffering capacity of hydrogen ions [2] and a fast tempo of lactate elimination. The level of acidosis in athletes, to a large extent, depends on the specifics of the sports training, mainly speed training and endurance, involving anaerobic systems, which plays a key role in the initial part of the fight [22]. Other authors also connect the high level of acidosis after the efforts at maximum intensity with of the initial amount of muscle glycogen [23,24]. In MMA fighters, high lactate concentrations ranging from 8.1 to 19.7 $mmol \cdot L^{-1}$ are noted after training [4]. The level of lactate after maximal exercise in the Greco-Italian wrestlers reached 18.0±2.7 $mmol \cdot L^{-1}$ [19]. For the studied fighter, the maximum lactate levels were 9.99 $mmol \cdot L^{-1}$ in the first series and 12.96 $mmol \cdot L^{-1}$ in the second series of the test, which is one of the positive effects of implemented training program.

Determining threshold load is important in the control of sports training because it allows to determine the optimal intensity of the training, causing the desired metabolic reactions of the system, and lead to increased physical endurance and strength [21]. For the fighter in this study, improvement of the monitored indicators at the second ventilatory threshold was noticed. The reason for this could be the realization of the running workout of near-threshold intensity, which during the 11-week observation period equaled 242 km. One of the basic elements of training program was the inclusion of running training. In the present study, training units during which efforts of near-threshold intensity took place throughout the period of observation even though the largest share was observed in the middle of the preparatory period.

Conclusions

The designed and implemented training program resulted in favorable changes in body composition of the studied fighter. After the training period, improvement in peak power of the upper limbs as well as aerobic power and effectiveness of elimination lactate were noted. Physiological measurements have therefore confirmed the effectiveness of this training method.

Declaration of interest

The authors report no conflicts of interest.

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Address for correspondence:
Łukasz Tota
University School of Physical Education
Institute of Biomedical Sciences
Jana Pawła II 78,
31-571 Krakow, Poland
+4812 6485222; lukasztota@gmail.com

Tomasz Drwal: drwaltomasz@gmail.com
Marcin Maciejczyk: marcin.maciejczyk@awf.krakow.pl
Zbigniew Szyguła: wfszygul@cyf-kr.edu.pl
Wanda Pilch: wanda.pilch@awf.krakow.pl
Pałka Tomasz: wfpalka@wp.pl
Grzegorz Lech: g.lech@wp.pl