ARCHIVES OF BUDO
Journal of Innovative Agonology

e-ISSN: 1643-8698

Section: ***SPORT SCIENCE & SPORT MEDICINE FOR HEALTH*** *Original Paper*

The influence of a 12-week training program developed to meet the menstrual cycle effects on special physical fitness, technical and tactical actions and heart rate variability indicators among female muay thai athletes

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Authors' Contribution:

A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

Received: date
Accepted: date 20.12.2024
Published: date 20.12.2024

Dictionary:

Muay thai– noun a martial art that is a form of kickboxing, practiced in Thailand and across Southeast Asia [33].

Macrocycle – noun a training cycle that typically lasts for a year [36].

Training session – noun a period of time during which an athlete trains, either alone, with a trainer or with their team [36].

Menstrual cycle – a series of natural changes in hormone production and the structures of the uterus and ovaries of the female reproductive system that makes pregnancy possible. The ovarian cycle controls the production and release of eggs and the cyclic release of estrogen and progesterone. The uterine cycle governs the preparation and maintenance of the lining of the uterus (womb) to receive an embryo. These cycles are concurrent and coordinated, normally last between 21 and 35 days, with a median length of 28 days. [Wikipedia].

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Abstract:

Background and Study Aim: The expansion of sports for women has served as an impetus for new research in martial arts. The aim of this study is knowledge about the influence of a 12-week training program developed to meet the menstrual cycle effects on special physical fitness, technical and tactical actions and heart rate variability indicators among female muay thai athletes.

Material and Methods: The study involved 28 female muay thai athletes with a regular 28-day menstrual cycle. They were divided into experimental (aged 20.79 ±1.93 years) and control groups (aged 21.07 ±1.38 years), engaging 14 persons each. The experiment was conducted during which the athletes of the experimental group were trained for 12 weeks by a training program designed to meet the menstrual cycle of women. The indicators of special physical fitness, technical and tactical actions in controlled sparring, heart rate variability indicators before and after the experiment were determined in female athletes of both groups.

Results: The differences in indicators ranged from 11.45 ($p < 0.05$) to 29.64% ($p < 0.01$). The analysis of intergroup differences of technical and tactical action indicators showed that after the experiment the number of strikes delivered was significantly higher among women of the experimental group by 9.76%, the ratio of attacking and defensive actions by 11.76% and 12.47% respectively, and the ratio of combat efficiency by 12.63% ($p < 0.05$). In the experimental group compared to the control group athletes, 16 out of the 17 analyzed parameters of heart rate variability changed significantly after 12 weeks of the experiment, during which the women were trained under different programs.

Conclusions: We determined the positive influence of a 12-week training program developed to meet the menstrual cycle on the indicators of special physical fitness, the number of strikes, the coefficients of attacking and defensive actions, the effectiveness of combat actions during sparring, as well as the heart rate variability indicators of female muay thai athletes. We are recommending this program for female muay thai athletes.

Keywords: combat sport, training process, cardiovascular system, physical activity, combat efficiency, sparring.

1. Introduction

Muay thai, a traditional martial art from Thailand, has grown in popularity over the past decade, gaining worldwide recognition as a dynamic and spectacular form of sport and cultural heritage [1, 2]. For centuries, the practice of this sport was deeply rooted in traditions that excluded women from active participation. Not only were they forbidden from competing in the ring, but even participating as spectators was unacceptable. This ban stemmed from superstitions that women's presence weakened competitors, taking away their strength, and even increasing the risk of injury [3].

The turning point came in the 1990s, when international interest in muay thai began to grow rapidly, and women began to actively participate in amateur world championships. This was an important event that broke centuries of barriers and opened the door to equality in the sport. Since then, women's role in muay thai has been constantly developing, and their presence in sports arenas has contributed to the popularization of the discipline around the world [1].

Today, women's muay thai fights are enjoying increasing interest and recognition. Female competitors demonstrate impressive technical skills, strength and determination, and their fights are just as exciting and spectacular as those fought by men. The development of women's muay thai is not only a sporting triumph, but also evidence of social and cultural evolution, which is redefining women's place in traditional sports disciplines [4, 5].With the growing interest of women in combat sports, the number of scientific studies devoted to the peculiarities of sports training of women engaged in freestyle wrestling [6, 7], judo [8-11], taekwondo [12, 13], boxing [14, 15] has increased. Over the last 35 years, experts in the field of theory and methodology of sports have conducted research aimed at studying the psychophysiological state, physical performance of female athletes of different ages and sports qualifications during the menstrual cycle in combat sports, in particular, in wrestling such as judo, freestyle wrestling [6, 17-19]. There is a sufficient number of studies devoted to the issues of designing the female training process in combat sports [16, 20, 21], however, a small number of works take into account the changes in the indicators of various motor qualities, functional and psychophysiological state of female athletes in different phases of the menstrual cycle [4, 8]. In percussive martial arts, the training process of women taking into account cyclic physiological changes in the female organism is represented fragmentarily [16], and the works in which the of physical activity planning is carried out taking into account the phases of the menstrual cycle are rare. However, there is a sufficient number of scientific works in which experts from other sports point out the need to take into account the changes occurring in the functional systems of the body in different phases of the menstrual cycle under the influence of the changing hormonal status of female athletes, when planning physical activity [20-22]. Experts indicate that highly qualified female athletes have reproductive system disorders, which are most pronounced in female athletes in combat sports, caused by hyperandrogenism combined with infertility and inability to bear a fetus in more than 30% of cases [23-27]. Consequently, the rational designing of the training process taking into account the peculiarities of the menstrual cycle is an urgent issue of women's sports training, in order to prevent and reduce complications in the form of reproductive disorders. Experts in women's sports point out that the most favorable phases for performing a large volume of high-intensity physical activity are postmenstrual and postovulatory phases, in turn, a decrease in special performance in female athletes is observed in

menstrual, ovulatory, and especially premenstrual phases [28, 29]. Irrational physical activity performed by women during this unfavorable period can lead to negative consequences in the form of overexertion, readaptation, failure of adaptation of female athletes [30-32].

Despite the large number of studies on women's sports, there is a lack of data on the designing of the training process of female muay thai athletes taking into account the phases of the menstrual cycle. The training process of female muay thai athletes is mainly based on the generally accepted method for men, without taking into account the peculiarities of the female body [33]. There is no data on how to distribute training means, determine the intensity and volume of the load performed during one menstrual cycle of female athletes. To ensure that this load contributes to the increase in the level of special physical fitness, technical and tactical fitness without compromising the functional state of the cardiovascular system of female muay thai athletes.

The aim of this study is knowledge about the influence of a 12-week training program developed to meet the menstrual cycle effects on special physical fitness, technical and tactical actions and heart rate variability indicators among female muay thai athletes.

2. Materials and Methods

Participants

The study involved 28 female muay thai athletes with regular 28-day menstrual cycle. Women did not take contraceptives, did not have any gynecological diseases or health abnormalities that would affect the menstrual cycle. They were divided into experimental and control groups of 14 persons each (Table 1). The experiment was conducted following the ethical standards for the study in humans as suggested by Declaration of Helsinki. Also, a written consent was received from female athletes to participate in the surveys. All participants were informed about the study procedures, benefits, risks and their obligations before signing informed consent. They were also informed that they could cease participation at any point, without any consequences.

Table 1. Characteristics of female muay thai athletes participating in experimental studies

Statistical Indicator	Age (years)	Experience (years)	Body height (cm)	Body mass (kg)
Experimental group (n = 14)				
Average mean	20.79	9.36	165.57	51.07
Standard deviation	1.93	0.93	5.50	5.08
Variation coefficient	9.28	9.93	3.32	9.94
Control group (n = 12)				
Average mean	21.07	9.14	165.86	51,79
Standard deviation	1.38	0.77	5.01	4,89
Variation coefficient	6.57	8.43	3.02	9,44

Design of research

The research was conducted on the premises of Wuhan Institute of Physical Education. The research was conducted in three stages. At the first stage, the examination of female athletes of experimental and control groups was carried out. Women were surveyed for the indicators of special physical fitness, of technical and tactical actions in controlled sparring, and for the heart rate variability indicators. At the second stage, the female athletes of the experimental group were trained according to the specially designed 84-day program (taking into account three 28-day menstrual cycles of female athletes). This program consisted of 15 microcycles: three retractive, six stress and six recovery microcycles. Each of the training microcycles corresponded to the phases of the menstrual cycle. Each menstrual cycle consists of menstrual (days 1-5), postmenstrual (days 6-12), ovulatory (days 13-15), postovulatory (days 16-24) and premenstrual (days 25-28) phases [18, 28, 29]. We applied this division of the menstrual cycle into five phases, as many experts in women's sports consider it the most rational, it is used in sports practice and allows us to take into account the phases of the cycle as separate training microcycles when planning physical activity in the mesocycle [26, 32]. The microcycle of high-intensity trainings corresponded to phases II and IV, retractive - to phase I, and recovery - to phases III and V of the MC (Table 2).

Athletes of the CG were trained according to the training program developed without taking into account the phases of the menstrual cycle. Women trained without adhering to the principle of reducing the physical activity in menstrual, premenstrual, ovulatory phases, increasing the activity in favourable, postmenstrual and postovulatory phases. The ratio of sports training means throughout the mesocycle was distributed without taking into account the changes occurring in the body in different phases of the menstrual cycle. In the menstrual phase, women also trained without adjusting the volume and intensity of physical activity, but they did not perform exercises on the abdominal muscles. At the third stage, a repeated examination of the female athletes of the experimental and control groups was carried out, immediately after the completion of the 12-week exercise program. We determined indicators of special physical fitness, of technical and tactical actions in controlled sparring, and heart rate variability indicators.

Table 2. Structure of training program of muay thai female athletes

Mesocycle Days	Microcycle, days		MC Phase, days		Priority orientation of sports training	Amount of load during exercises in microcycles	Volume of load (min)	Type of training
1-5	1st Retr	1		1	Rest	–		
29-33	2nd Retr.	2		2	Technical training	1, 2, 3: small		
57-61	3rd Retr.	3	I	3	SPT, speed and strength abilities and flexibility	1, 2, 3: small	90	Supporting
		4		4	Technical training	1, 2, 3: medium		
		5		5	SPT, endurance and coordination abilities	1, 2, 3: medium		
6-12	1st HIT.	1		6	Technical and tactical training	1: medium; 3, 5: big		
34-40	3rd HIT .	2		7	SPT, speed and strength	1, 3, 5: medium		
62-68	5th HIT .	3		8	Rest	–		
		4	II	9	SPT, speed and strength abilities and flexibility	1, 3, 5: big	120	Developing
		5		10	Technical and tactical training	1, 3: medium; 5: big		
		6		11	SPT, endurance and coordination abilities	1, 3, 5: big		
		7		12	Technical and tactical training	1, 3, 5: medium		
13-15	1st Rec.	1		13	SPT, speed and strength	1, 3, 5: medium		
41-43	3rd Rec.	2	III	14	Technical training	1, 3, 5: small	90	Recovery
69-71	5th Rec.	3		15	Rest	–		
16-24	2nd HIT .	1		16	Technical and tactical training	2, 4, 6: big		
44-52	4th HIT .	2		17	SPT, speed and strength abilities and flexibility	2, 4, 6: medium		
72-80	6th HIT .	3		18	Technical and tactical training	2, 4, 6: big		
		4		19	SPT, endurance and coordination abilities	2, 4, 6: medium		
		5	IV	20	Technical and tactical training	2, 4, 6: big	120	Developing
		6		21	SPT, speed and strength	2, 4: medium; 6: big		
		7		22	Rest	–		
		8		23	Technical and tactical training	2, 4, 6: big		
		9		24	SPT, speed and strength abilities and flexibility	2, 4, 6: medium		
25-28	2nd Rec.	1		25	Technical training	2, 4, 6: medium		
53-56	4th Rec.	2	V	26	SPT, endurance, coordination abilities	2, 4, 6: small	90	Recovery
81-84	6th Rec.	3		27	Technical training	2, 4, 6: small		
		4		28	SPT (GPP excluded)	2, 4, 6: small		

Notes: I – menstrual phase of the cycle; II – postmenstrual; III – ovulatory; IV – postovulatory; V – premenstrual; Retr. – retractory; Str. – stress; SPT- special physical training, Rec. – recovery microcycle; Retr. - retractive microcycle, Str. – microcycle of high-intensity training.

Data collection

To determine the special physical fitness, a test was conducted, which included a 3-minute combined test. It included 9 exercises: two-sided double punches: straight left hand jab - body straight right knee strike (quantity of combinations); – two-sided double punches: right hand jab – body straight left knee strike (quantity of combinations); – one-sided combinations of a straight right knee, left knee strikes (number of strikes); – two-sided combinations of straight knee strikes (number of strikes); – three-punches combinations of hands: straight left hand punch - straight right hand punch - side left hand punch (quantity of combinations); – one-sided combinations of side strikes by left leg, by right leg (quantity of combinations); – two-sided combinations of strikes by elbows: straight strikes by the left elbow - by the right elbow - side strikes by the left elbow - by the right elbow - side roundhouse strike by the right elbow (quantity of combinations) [4]. During the test, the female athletes consistently performed technical actions (various strikes), each exercise lasting for 20 seconds, without any breaks between exercises. After the test was completed, the number of strikes and the number of series of strikes in the tests were counted, as well as the total number of strikes performed by the athletes within the combined 3-minute test. To determine the indicators of technical and tactical actions, controlled sparring sessions were organized between women of the experimental and control groups. The sparring was conducted in accordance with the rules of Muay Thai competitions, consisted of three rounds of 2 minutes each, the break between rounds was 1 minute. Video shooting of each round was carried out using an iPhone 14 ProMax video camera, which was mounted on a fixed tripod.

The following indicators of technical and tactical actions were determined: the total number of strikes delivered during three rounds (3 rounds 1 min each), the coefficient of attacking actions, the coefficient of defensive actions and the coefficient of combat efficiency. The coefficient of attacking actions is the ratio of the number of strikes that reached the target to the number of all strikes by the boxer. It is calculated by the formula: CATT = n / N, where n is the number of strikes that reached the target; N is the total number of strikes. The coefficient of defensive actions is the ratio of the number of parried strikes to the total number of strikes by the attacker. It is calculated by the formula: CDEF = (N-n) / N, where N is the total number of strikes delivered by the opponent; n is the number of opponent's strikes that reached the target; N-n is opponent's strikes that did not reach the target [33].

The examination of women to determine heart rate variability was conducted in the morning at rest in the supine position, before physical activity, the day before the examination did not include high-intensity training sessions. The "Cardio+" (Ukraine) diagnostic automated system was used to monitor the functional state, which includes electrocardiograph (ECG), rhythmocardiograph [2, 34, 35]. To assess indicators of heart rate variability we used the following indices: HR heart rate (bpm); SDNN standard deviation of RR (s); PNN50 percentage (share) of successive RR (%); RMSSD (root mean square of the successive differences), (ms); IVE - index of vegetative equilibrium (relative units), VRI - vegetative rhythm index (r.u.); SI - stress index (r.u.), (ms); ΔRR mean of variation of RR (ms); Mo mode of RR (s); AMo - amplitude of the mode of RR (%); LF low frequency of HRV (ms^2; %); HF higher frequency of HRV (ms^2; %); VLF very low frequency of HRV (ms^2; %); LFn - LF in normalized units LF/(TP- VLF)=100; HFn - HF in normalized units HF/(TP-VLF)=100; TP total power of the heart rate spectrum (ms2); RSAI regulatory systems' activity indicator (scores).

Statistical analysis

The statistical analysis of data is performed by means of the licensed Statistical Packages for the Social Science (SPSS) version 22.0 (IBM Corporation, Somers, NY, USA). After assessing the normality of the data with the use of the Kolmogorov–Smirnov test, the means and standard deviations were calculated for all variables. It was defined the indicators of descriptive statistics: arithmetic mean value ($\overline{x}$), standard deviation (SD or ±) and error of mean (m), variation coefficient (V). The significance of differences in groups was estimated by means of Student's test (t). In the studies, the level of at least $p < 0.05$ and higher was shown as statistically significant differences.

3. Results

Indicators of special physical fitness of female athletes of the experimental and control groups during the experiment and after its completion presents in table 3. An intragroup analysis of the indicators of special physical fitness of female athletes of the experimental group showed that after the pedagogical experiment, the indicators in all nine exercises of the combined 3-minute test increased significantly ($p < 0.05$, $p < 0.01$). The increase in pedagogical testing results ranged from 14.27 to 60.48%. In the control group, there is also an increase in indicators of special physical fitness of female athletes, but significant changes were noted only in two exercises - direct knee strikes, where the result increased by 2.23 times on average for the group, which amounted to 10.08% ($p < 0.05$). Statistically significant changes were observed in the seventh exercise - left leg side strikes, where the increase was 1.54 kicks, which corresponded to 10.94% ($p < 0.05$) (Table 3).

The women of the experimental group in comparison with the athletes of the control group, after the experiment, showed significant differences in eight exercises of the combined test ($p < 0.05$, $p < 0.01$). Significant changes were detected in the second, third, seventh, eighth and ninth exercises, with differences ranging from 18.24% to 29.64% ($p < 0.01$). Differences in the fourth, fifth and sixth exercises, performed by athletes of the experimental group in comparison with the control group vary in the range from 11.45 to 17.63% ($p < 0.05$).

The analysis of intragroup differences in the indicators of technical and tactical actions revealed that before the pedagogical experiment, the four studied indicators did not differ significantly between the athletes of the experimental and control groups ($p > 0.05$). The repeated study showed that in the experimental group, in comparison with the initial data, all the studied indicators significantly increased ($p < 0.05$, $p < 0.01$). In the control group, one parameter of technical and tactical actions - the coefficient of attacking actions ($p < 0.05$) changed significantly. The analysis of intergroup differences of technical and tactical action indicators showed that after the experiment the number of strikes delivered was significantly higher in women of the experimental group, the differences was 9.76% ($p < 0.05$). The coefficients of attacking and defensive actions in the experimental group are significantly higher and differ from the data of the control group athletes by 11.76 % and 12.47% respectively ($p < 0.05$). Also, the coefficient of combat efficiency is significantly higher in the athletes of the experimental group in comparison with the control group by 12.63% ($p < 0.05$) (Table 4).

Table 3. Changes in the indicators of special physical fitness of female athletes specializing in muay thai during and after the pedagogical experiment

Test	Statistical indicator: $\bar{x}$ SD						Magnitude of differences $EG_2 - CG_2$	t
	Experimental group (n = 14)			Control group (n = 14)				
	prior to the experiment (1)	at the end of the experiment (2)	t	prior to the experiment (1)	at the end of the experiment (2)	t		
Straight left hand punch − side strike by right leg to the torso in 20 s, number of series	14.44 ±0.91	**16.5** ±0.89	−2.24*	14.46 ±0.88	15.33 ±1.44	−1.03	1.17	1.43
Straight right hand punch − side strike by left leg to the torso in 20 s, number of series	14.90 ±0.90	**18.88** ±1.88	−2.59*	15.01 ±0.81	15.28 ±2.44	−0.27	**3.60**	4.22**
Straight right knee strikes in 20 s, number of strikes	22.96 ±1.11	**28.28** ±1.65	−7.09**	22.93 ±1.12	23.12 ±2.48	−0.36	**5.16**	3.81**
Straight left knee strikes in 20 s, number of strikes	22.18 ±1.07	**26.12** ±2.27	−2.77*	22.19 ±1.05	23.13 ±1.65	−1.88	**2.99**	2.47*
Straight knee strikes in 20 s, number of strikes	22.07 ±1.20	**28.66** ±2.48	−7.47**	22.09 ±1.18	**24.32** ±1.98	−3.05*	**4.34**	2.63*
Straight left hand punch – Straight right hand punch − side left hand punch in 20 s, number of series	11.27 ±0.76	**14.52** ±1.32	−7.78**	11.24 ±0.75	11.96 ±2.01	−0.56	**2.56**	2.44*
Side strikes by left leg in 20 s, number of strikes	13.83 ±1.27	**22.2** ±1.72	−8.29**	14.08 ±1.23	**15.62** ±1.66	−3.21*	**6.58**	7.11**
Side strikes by right leg in 20 s, number of strikes	13.87 ±1.30	**21.1** ±1.35	−8.95**	14.16 ±1.35	15.27 ±1.88	−0.59	**5.83**	6.43**
Straight strikes by the left elbow-by the right elbow − side strikes by the left elbow − by the right elbow − side roundhouse strike by the right elbow in 20 s, number of series	5.36 ±0.69	**7.28** ±1.23	−8.12**	5.39 ±0.79	5.45 ±0.32	−0.21	**1.83**	6.12**

* – $p < 0.05$, ** – $p < 0.01$, Student's *t*-test

Table 4. Changes in the indicators of technical and tactical actions in control sparring of female athletes specializing in muay thai during and after the pedagogical experiment

Test	Statistical indicator: $\bar{x}$ SD							
	Experimental group (n = 14)			Control group (n = 14)			Magnitude of differences $EG_2 - CG_2$	t
	prior to the experiment (1)	at the end of the experiment (2)	t	prior to the experiment (1)	at the end of the experiment (2)	t		
Number of strikes performed	94.50 ±2.58	**107.71** ±2.89	−3.26*	96.15 ±2.47	97.20 ±4.32	−1.14	**10.51**	3.62*
Coefficient of attacking actions	0.26 ±0.01	**0.34** ±0.03	−8.48**	0.27 ±0.03	**0.30** ±0.04	−3.27*	**0.04**	3.71*
Coefficient of defensive actions	0.52 ±0.02	**0.61** ±0.04	−3.31*	0.51 ±0.02	0.53 ±0.03	−1.42	**0.08**	4.36*
Coefficient of combat efficiency	0.78 ±0.02	**0.95** ±0.05	−3.63*	0.78 ±0.02	0.83 ±0.04	−1.69	**0.12**	3.11*

* – $p < 0.05$, ** – $p < 0.01$ Student's *t*-test

Table 5. Changes in heart rate variability indicators of female athletes specializing in muay thai during and after the pedagogical experiment

HRV indicator	Statistical indicator: $\bar{x}$ SD Experimental group (n = 14)			Control group (n = 14)			Magnitude of differences $EG_2 - CG_2$	t
	prior to the experiment (1)	at the end of the experiment (2)	t	prior to the experiment (1)	at the end of the experiment (2)	t		
HR (bpm)	66.36 ±3.91	**59.11** ±4.35	2.76*	66.89 ±4.27	68.88 ±4.32	−1.21	**−9.77**	−2.78*
Mo (s)	0.74 ±0.04	0.79 ±0.03	−1.13	0.73 ±0.42	**0.64** ±0.06	3.44*	**0.15**	3.42*
AMo (%)	34.72 ±4.35	**31.14** ±2.20	3.21*	35.14 ±2.83	**39.95** ±3.62	−2.92*	**−8.81**	−5.81**
IVE (r.u.)	117.86 ±7.06	**100.22** ±9.56	2.82*	115.44 ±10.76	126.62 ±10.98	−1.77	**−26.40**	−2.67*
VRI (r.u.)	4.65 ±0.71	4.44 ±0.12	1.37	4.45 ±0.16	**5.65** ±0.58	−7.27**	**−1.21**	−2.64*
SI (r.u.)	74.89 ±17.91	**58.38** ±9.53	8.91**	74.89 ±11.67	**99.36** ±16.89	−8.66**	**−40.98**	−9.32**
RSAI (scores)	2.02 ±1.44	**1.43** ±0.37	7.09**	2.11 ±0.48	**3.86** ±1.72	−10.52**	**−2.43**	−9.14**
SDNN (ms)	43.04 ±7.54	**49.16** ±3.67	−2.92*	42.58 ±4.65	**37.26** ±4.87	2.83*	**11.90**	3.43*
RMSSD (ms)	52.21 ±4.79	54.40 ±1.10	−1.45	53.10 ±0.92	48.33 ±2.61	1.22	**6.07**	1.15
PNN50 (%)	41.90 ±6.09	**56.14** ±8.33	−7.91**	41.54 ±10.32	**34.38** ±9.12	2.78*	**21.76**	8.36**
TP (ms^2)	1979.22 ±234.88	**2235.23 ±152.08**	−3.36*	1964.98 ±191.1	**1748.22** ±199.23	2.92*	**487.01**	3.15*
LF (ms^2)	698.92 ±150.79	**786.80** ±69.36	−3.21*	649.92 ±96.79	**537.38** ±104.02	3.17*	**249.42**	3.34*
HF (ms^2)	548.80 ±140.69	**824.22** ±156.48	−7.57**	557.80 ±188.39	**421.41** ±169.31	4.31*	**402.81**	8.86**
VLF (ms^2)	726.23 ±86.51	**624.45** ±63.19	2.74*	740.23 ±81.87	**821.43** ±80.84	−3.12*	**−196.98**	−2.86*
LFn (r.u.)	56.26 ±6.40	**48.85** ±4.07	2.69*	55.46 ±4.67	59.26 ±5.44	−0.35	**−10.41**	−2.78*
HFn (r.u.)	43.74 ±6.13	**51.15** ±3.34	−3.18*	44.54 ±3.88	40.74 ±4.39	1.38	**10.41**	3.11*
LF/HF	1.34 ±0.35	**0.92** ±0.23	7.87**	1.29 ±0.26	**1.51** ±0.23	−2.84*	**−0.59**	−8.56**

AMo amplitude of the mode of RR; **IVE** index of vegetative equilibrium; **HFn** - HF in normalized units HF/(TP-VLF)=100; **HF** higher frequency of HRV; **HR** heart rate; **LFn** - LF in normalized units LF/(TP- VLF)=100; **LF** low frequency of HRV; **Mo** mode of RR; **PNN50** percentage (share) of successive RR; **RMSSD** root mean square of the successive differences; **RSAI** regulatory systems' activity indicator; **SDNN** standard deviation of RR; **SI** stress index; **TP** total power of the heart rate spectrum; **VLF** very low frequency of HRV; **VRI** vegetative rhythm index; * – $p < 0.05$, ** – $p < 0.01$, Student's *t*-test

The analysis of intragroup differences of heart rate variability indicators of female athletes of the experimental group demonstrated that after the experiment 14 HRV indicators differed from the initial data at a statistically significant level ($p < 0.05$, $p < 0.01$). The changes affected five out of seven statistical indicators of heart rate variability, such as: HR, AMo, IVE, SI, RSAI, the range of differences varies from 10.31% to 29.21%. As well as two temporal - SDNN, PNN50 and seven spectral indicators reflecting the predominance of sympathetic or parasympathetic type of autonomic regulation of heart rate, among them: TR, LF, HF, VLF, LFn, HFn, LF/HF, where the range of differences varied from 13.17% to 50.19% (Table 5).

In the group of female athletes of the control group, 12 out of 17 indicators changed significantly in comparison with the initial data ($p < 0.05$, $p < 0.01$). They showed a shift in the type of vegetative regulation towards sympathotonia, as well as moderate tension of regulatory systems on average in the group, while six female athletes showed pronounced tension of regulatory systems, and two of them showed overstrain of regulatory systems. Such HRV indicators as the regulatory systems activity index (RSAI), SI and VRI changed significantly, showing increase by 82.94%, 32.68% and 26.97% respectively ($p < 0,01$). HF, SDNN, PNN50, TR, LF, Mo indicators decreased significantly, where the range of differences varies from 11.03% to 24.45% ($p < 0.05$).

The athletes of the experimental group, compared to the athletes of the control group, 16 of the 17 analyzed parameters significantly changed after the 84-day experiment, during which the women trained under different programs. The most pronounced differences were found in such indicators as the regulatory systems activity index (RSAI), SI, LF/HF, HF, the range of differences varies from 48.87% to 169.93% ($p < 0.01$). In the experimental group there was a significant increase, and in the control group a decrease in such indicators as: SDNN, PNN50, TR, LF, HF, HFn. Also, in the experimental group a significant decrease, and in the control group a significant increase, of the following indicators of heart rate variability was revealed: HR, AMo, IVE, SI, RSAI, VLF, LFn, LF/HF.

4. Discussion

The sports result in muay thai depends on the indicators of special physical fitness, technical and tactical actions and the level of functional state of athletes [4, 5]. For the first time we conducted a study that included the development of a 12-week program taking into account the menstrual cycle of female muay thai athletes and evaluation of its effectiveness. The training program was developed taking into account the peculiarities of cardiorespiratory and vegetative nervous systems, special physical fitness during the menstrual cycle of female muay thai athletes. In combat sports such as judo [8], taekwondo [19], experts also developed training programs for women, but their duration was equal to 28 days, which corresponded to one menstrual cycle of female athletes. In our studies, the training microcycles, which were included in the 12-week training program, corresponded to the phases of the menstrual cycle of female athletes. Our research coincides with Chistyakova's data, in which the author proposed to divide the training 28-days mesocycle into five microcycles - retracting, two stress and recovery. Other experts preferred to divide the training mesocycle into four microcycles: special (days 27-28, days 1-5 of the cycle), first stress (days 6-12), discharge (days 13-17) and second microcycle of high-intensity training (days 18-26) [29, 32]. A distinctive feature of the 12-week program developed by us is the use of training sessions with different amounts of physical activity and means of sports training, taking into account the functional state in different phases of the

menstrual cycle of female athletes [28]. When planning the physical activity of female muay thai athletes during the monthly mesocycle, it is necessary to take into account the physiological features of the female body and reduce the stress in the menstrual, premenstrual, ovulatory phases, and increase the load in the postmenstrual and postovulatory phases of the menstrual cycle [28].

In the retracting microcycles, the emphasis is mainly placed on the development of technical fitness of female athletes, individual training of the technique of punches, elbowings and defensive actions against them while walking and for an each step, from a fighting stance in movement is performed. In microcycle of high-intensity trainings, the priority focus of sports training is general and special physical training and improvement of technical and tactical actions of female athletes in pairs with a partner in controlled sparring and conditional fights, simulating the conditions of upcoming competitions. In recovery microcycles, athletes along with the development of coordination abilities, speed, strength and endurance are offered to individual performance while walking and for an each step of all attacking and defensive actions of thai boxing, from a fighting stance in the movement and in the clinch. The microcycle of high-intensity trainings corresponded to the postmenstrual and postovulatory phases, retractive microcycles corresponded to the menstrual phase, and recovery microcycles corresponded to the ovulatory and premenstrual phases of the female athletes' menstrual cycle. In our research, we determined that the proposed activity, distributed taking into account the phases of the menstrual cycle, had a positive effect on the indicators of special physical fitness of women actively engaged in muay thai. It should be noted that during the testing of special physical fitness, the athletes consistently performed technical actions (various strikes), each exercise lasting 20 seconds, the break between exercises was excluded, so we evaluated not only the number of strikes and series of strikes in the exercise, but also the amount of strikes within 180 seconds. In our opinion, this indicator the most objectively demonstrated how much the special endurance of female athletes, necessary for successful competitive activity, expressed in the ability to deliver the highest number of strikes in conditions of accumulated fatigue and increasing lactic acid values, has changed. The indicator of the total number of strikes delivered by the athletes of the experimental group within the combined 3-minute test after the pedagogical experiment underwent significant changes ($p < 0.01$). Differences in the total number of strikes after the pedagogical experiment and initial data in the experimental group corresponded to 29,41% ($p < 0,01$). The value of differences between the indicators of the total number of strikes of the athletes of the experimental group after the experiment exceeded the indicators of the athletes of the control group by 55.61 strikes, which corresponded to 22.2% ($p < 0.01$).

Technical and tactical preparedness in combat sports is one of the leading components of athletes' preparedness, which determines the result of competitive bouts [4, 8, 16]. The results of our research confirm the data [8], that training programs, developed taking into account the menstrual cycle of female athletes, can improve the indicators of technical and tactical readiness. Our research also confirms the available data on the positive effect of physical activity distributed taking into account the menstrual cycle in training programs on heart rate variability indicators [30, 32]. In our research, it was determined that female athletes had a shift in the vegetative balance towards parasympathotonia, a more economical type of vegetative regulation. Such indicators as RSAI, LF/HF decreased significantly, and PNN50 and HF increased significantly ($p < 0,01$). In the group of female athletes, who were trained according to our program,

a significant decrease in the share of the power spectrum of ultra-low frequency oscillations of the heart rate spectrogram, characterized by the VLF parameter, was observed ($p < 0.05$). These changes indicate a decrease in humoral and metabolic effects on the regulation of heart rhythm. In the control group of female athletes who trained without taking into account their menstrual cycle, it was determined that the physical activity performed by the athletes caused negative reactions of the cardiovascular system. It was revealed, in consequence of the performed physical activity they had marked tension of regulatory systems, increased activity of sympatho-adrenal system, pituitary-adrenal system, when for normal functioning it is required to spend functional reserves of the organism. After the experiment they also showed a decrease in the resources of the organism, which is signaled by a significant decrease in the index of TP (total power of the heart rate spectrum, ms^2).

5. Conclusions

As a result of the conducted research, the positive influence of the developed training program designed for 84 days, which corresponds to three menstrual cycles of female muay thai athletes (28 days each), on the indicators of special physical fitness, on the number of strikes, the coefficients of attacking and defensive actions, the effectiveness of combat actions during sparring is shown. As well as the improvement of functional state of cardiovascular system of female athletes, which manifested itself in a decrease of stress-index and a shift in the type of vegetative regulation of heart rhythm towards parasympathotonia with predominance of normotonia, the presence of optimal tension of regulatory systems, economization of cardiovascular system activity, a high level of recovery potential.

Data Availability Statement: The data supporting this study's findings are available from the corresponding author upon reasonable request.

Conflicts of Interest: The authors declared no conflict of interest.

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Citation: Cherkashina E, Cherkashin I, Kruszewski M et al. The influence of a 12-week training program developed to meet the menstrual cycle effects on special physical fitness, technical and tactical actions and heart rate variability indicators among female muay thai athletes. Arch Budo J Inn Agon 2024, 20: 75-89