ORIGINAL ARTICLE

Influence of a 16-week training program with *Muay Thai* components on BMI, body composition, and risk of sudden cardiac death among obese men

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
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Abstract

Background and Study Aim: Physical activity is an essential component of a non-drug therapy method for obese individuals. Aim of this study is knowledge about influence of a 16-week training program with *Muay Thai* components on BMI, body composition, and the risk of sudden cardiac death among obese men.

Material and Methods: The study involved 24 obese men with BMI 36.49 ±4.05 kg/m^2. They were divided into experimental and control groups of 12 persons each. The experimental group consisted of men aged 47.83 ±5.73 years, including six persons with class I obesity (BMI = 30.40 to 34.56 kg/m^2), three with class II obesity (BMI = 35.57 to 37.50 kg/m^2) and also three with class III obesity (BMI = 40.01 to 46.60 kg/m^2). The control group consisted of men aged 47.17 ±5.38 years, including four persons with class I obesity (BMI = 31.00 to 32.93 kg/m^2), five with class II obesity (BMI = 35.32 to 38.30 kg/m^2) and three with class III obesity (BMI = 40.90 to 43.60 kg/m^2). During the experiment the experimental group was engaged in a special 16-week training program with *Muay Thai* components. Body weight, BMI, body component composition, and risk of sudden cardiac death (according to ECG data and heart rate variability) were measured twice before and after the experiment. The men of the experimental group underwent pedagogical testing twice.

Results: A reliably significant decrease in body weight, BMI, and body fat percentage in general and separately in the limbs and abdomen was found among men of the experimental group after 16 weeks of training with *Muay Thai* components ($p<0.05$). The men in the experimental group, relative to the control group, 10 HRV (heart rate variability) indicators had shown reliably significantly improvement, which had a positive effect on the activity of the cardiovascular system. As a result, the risk of sudden cardiac death decreased among men of the experimental group. Their physical fitness indicators ($p<0.05$) had also shown significant increase.

Conclusions: We determined the positive influence of a 16-week training program with *Muay Thai* components on body weight, BMI, body component composition, heart rate variability, risk of sudden cardiac death, and physical fitness of obese men. We are recommending this program for obese men in their 40s and 60s who follow a sedentary lifestyle.

Keywords: body mass • cardio-vascular system • heart rate variability • obesity therapy • physical activity

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Metabolic syndrome – ***noun*** a medical condition characterized by symptoms such as obesity, diabetes, hypertension and high cholesterol [41].

Obesity –***noun*** the condition of being seriously overweight [41].

Obstructive sleep apnea (**OSA**) – is the most common sleep-related breathing disorder and is characterized by recurrent episodes of complete or partial obstruction of the upper airway leading to reduced or absent breathing during sleep. These episodes are termed "apneas" with complete or near-complete cessation of breathing, or "hypopneas" when the reduction in breathing is partial. In either case, a fall in blood oxygen saturation, a disruption in sleep, or both may result. A high frequency of apneas or hypopneas during sleep may interfere with restorative sleep, which – in combination with disturbances in blood oxygenation – is thought to contribute to negative consequences to health and quality of life [44].

Muay Thai– ***noun*** a martial art that is a form of kickboxing, practiced in Thailand and across Southeast Asia [41].

The "18 forms of Taiji-qigong" complex – was developed by the famous martial artist Lin Hou Sheng in the 1970s based on old Taoist systems. Taiji-qigong is a synthesis of Taijiquan and qigong breathing exercises. The system of his exercises is based on the principles of Taijiquan – softness and uniformity, smoothness and slowness, continuity of movements. These features were combined with concentration techniques from the qigong arsenal. The movements of the complex consisting of

INTRODUCTION

Obesity is the most common and dangerous disease of the 21st century [1-3]. Obese persons suffer from type 2 diabetes, arterial hypertension, coronary heart disease, obstructive sleep apnoea (OSA), musculoskeletal system and digestive system pathology [4-6]. Every year, the number of obese persons is growing all over the world [1, 6]. Many experts give an important role in the treatment of obesity to physical activity, as one of the main means of non-drug therapy [7-10]. The authors recommend the intensity of training at the level of 50-85% of the maximum oxygen consumption or 60-80% of the maximum heart rate [11-14].

Experts suggest performing aerobic physical activity (running, walking in normal conditions or using treadmills, cycling, exercise bike) in a continuous mode [13-16]. High-intensity training with the use of cycle ergometers and strength exercises has also been proven to be effective in combating excess weight [17, 18]. To reduce body weight and BMI (body mass index) indicators, resistance training is widely used in practice [13, 19-21]. Combined training programs have also been shown to be effective in reducing body weight and improving the performance of overweight and obese men. When moderate or high-intensity aerobic exercises are performed in one training session, exercises are used to develop the strength of various muscle groups [13, 20, 21]. Weight loss also depends on the duration of one training session, the frequency of training sessions per week, and the duration of the training program [20]. As the authors note, classes of at least 30 minutes a day, five times a week for 12 weeks or more are effective [13, 19, 20].

However, planning physical activities is complicated by the fact that overweight and obese individuals suffer from concomitant diseases of the cardiovascular system and musculoskeletal system [22-24]. Therefore, aerobic exercise should be planned with caution in order to avoid negative effects on the heart and cardiovascular system in general, injury to the joints and ligaments [25]. The course of exercises aimed at reducing body weight for middle-aged men is complicated by low motivation to perform a certain type of motor activity [25, 26]. Since obesity is accompanied by a decrease in testosterone and sexual dysfunction [27-29], obese and overweight men are increasingly required to attend health exercises with components of martial arts. However, there are few studies on the use of martial arts to reduce BMI [30]. They mostly concern overweight and obese women [31-36].

There are data on the use of kyokushin karate classes to reduce body weight, change the component composition of the body, and improve the posture of overweight primary school children [37]. In health-related weight-loss exercises, specialists used taijiquan for 45 minutes [34, 35], one hour [31-33] three times a week to reduce the girth and BMI of overweight women. At the same time, the diet was corrected and the caloric intake was reduced [31, 36]. One study examined the influence of performing martial arts in pre-menopausal women's weight loss exercises. During the exercises, women performed components of striking techniques of taekwondo, karate, kung-fu, boxing, kickboxing, *Muay Thai*, judo, aikido and jujitsu [36]. No data were found on the use of martial arts to correct body weight, reduce BMI in overweight and obese men aged 40-60 years.

There is an impressive list of literary works on various options for using motor activity in exercises to reduce BMI indicators, change the biochemical blood test indicators of overweight and obese men and women [14, 35, 38, 39]. However, studies aimed at developing a program of training sessions with the use of *Muay Thai* components in order to correct body weight, change the component composition of the body, increase the functional state, and level of physical fitness of obese middle-aged men have not been found.

Aim of this study is knowledge about influence of a 16-week training program with *Muay Thai* components on BMI, body composition, and the risk of sudden cardiac death among obese men.

MATERIAL AND METHODS

Participants

The study involved 24 obese men with BMI 36.49 ±4.05kg/m^2. They were divided into experimental and control groups of 12 persons each. The experimental group consisted of men aged 47.83 ±5.73 years, including six persons with class I obesity (BMI = 30.40 to 34.56 kg/m^2), three with class II obesity (BMI = 35.57 to 37.50 kg/m^2), three with class III obesity (BMI = 40.01 to 46.60 kg/m^2). The control group consisted of men aged 47.17 ±5.38 years, including four persons with class I obesity (BMI = 31.00 to 32.93 kg/m^2), five with class II obesity (BMI = 35.32 to 38.30 kg/m^2), three with class III obesity (BMI = 40.90 to 43.60 kg/m^2). When forming groups, the calculated indicator of the homogeneity criterion by age, body length, body weight, and BMI was taken into account (Table 1). The variation factor does not exceed 20% in any case, which indicates the uniformity of the examined groups.

All men gave their written consent to participate in the surveys. The experiment was conducted following the ethical standards for the study in humans as suggested by Declaration of Helsinki.

Design of research

The research was conducted in three stages. At the first stage, men of the experimental and control groups underwent physiological examinations. They included determination of body length and weight, calculation of BMI, component composition of the body, determination of a risk of sudden cardiac death (according to ECG data, indicators of heart rate variability at rest). Physical fitness indicators were also determined among the men of the experimental group.

At the second stage, the men of the experimental group trained for 16 weeks under special weight loss program in a gym. Exercises were held 5 times a week (except weekends Saturdays and Sundays) under the guidance of a qualified instructor. The duration of exercises was 90 minutes. The training consisted of a warm-up (15 mins), the main part: an aerobic module (30 mins), strength module (15 mins) and the final part (30 mins).

The warm-up included general development exercises, continuous walking for 4 minutes according to the scheme: 30 seconds at a normal pace, 30 seconds at the fastest pace (without switching to running).

The aerobic module included continuous contactless performance of striking and defensive *Muay Thai* techniques for 30 minutes. Members performed striking actions: knee strikes; punches: straight, side, uppercut, spinning. Elbow strikes: straight, side, spinning. Kicks: straight, side, spinning to the torso and head. Defensive actions included defensive movements against punches: slipping, bobbing, and against kicks: grabs, blocking, blocks.

18 exercises are simple, it is very effective as a means of preventing diseases and promoting health. It is necessary to observe the accuracy of performing stances, the uniformity and slowness of movements. Also with the consistency of breathing with movements, and you need to inhale through the nose, and exhale through the mouth. The complex can be performed in three modes: medical or gentle mode 3-fold repetition; standard mode-6-fold repetition and advanced mode (given a good physical fitness) 9 to 12-fold repetition [40].

Body mass index – *noun* an index that expresses adult weight in relation to height calculated as weight in kilograms divided by height in metres squared. Abbreviation BMI (NOTE: A body mass index of less than 25 is considered normal, and one of over 30 implies obesity) [41].

Sudden cardiac death describes the unexpected natural death from a cardiac cause within a short time period, generally ≤1 h from the onset of symptoms, in a person without any prior condition that would appear fatal [42, 43].

QRS – the **QRS complex** is the combination of three of the graphical deflections seen on a typical **electrocardiogram (ECG or EKG)**. It is usually the central and most visually obvious part of the tracing; in other words, it's the main spike seen on an ECG line. It corresponds to the **depolarization** of the right and left **ventricles** of the **human heart** and contraction of the large ventricular muscles [45].

QTc – the corrected (relative to the heart rate) value of the QT interval RR – the distance between this QRS complex and the one preceding it, expressed in seconds [46].

Table 1. Characteristics of obese men participating in experimental studies

Statistical Indicator	Age (years)	Body length (cm)	Body weight (kg)	BMI kg/m^2)
Experimental group (n = 12)				
Average mean	47.83	173.33	110.08	36.51
Standard deviation	5.73	0.06	15.48	4.65
Variation coefficient	11.97	3.37	14.06	12.71
Control group (n = 12)				
Average mean	47.17	172.00	107.84	36.49
Standard deviation	5.38	0.05	11.59	4.06
Variation coefficient	11.41	2.80	10.74	11.12

The strength module included exercises with body bar (6-8 kg): jerk, push, squat. As well as strength training without weights with your own weight to develop the strength of the muscles of the upper and lower limbs and torso: walking lunges, knee push-ups, supine leg raises, sit-ups, supine row.

Only 5 exercises aimed at developing the strength of different muscle groups were performed in one session. Men performed each exercise for 1 min in one set, one set per session, and rest between sets for 1 min.

In the final part, the men performed the “18 forms of Taiji-qigong” complex [40]. During the performance of movements, special attention was paid to the consistency of breathing with movements, and it is necessary to inhale through the nose, and exhale through the mouth. The complex was performed in a gentle mode 3-fold repetition. This was done for participants’ body recovery. Stretching was also performed. At the end of the experiment, the men performed a “Standing pole” meditation, which lasted 1 minute at the beginning of the experiment, 2 minutes at the fifth week. On the 8th to 10th week of exercises 3 minutes, on the 11th to 13th week 4 minutes, on the 14th to 16th week 5 minutes.

The control group members ran 3 times a week for 16 weeks (Mondays, Wednesdays, Fridays), the duration of each session was 60 mins, including running for 45 minutes at 50-70% of the maximum heart rate level and warm-ups for 15 mins. Sessions were held in the track and field arena.

At the third stage, members of the experimental and control groups were re-examined. Body weight, BMI, component composition of the body, and the risk of sudden cardiac death were determined. In the experimental group, physical fitness was also determined.

The “Cardio+” (Ukraine) diagnostic automated system was used to monitor the functional state, which includes electrocardiograph (ECG or EKG), rhythmocardiograph. To assess indicators of heart rate variability we used the following indices: **RR** respiratory rate (s); **SDNN** standard deviation of RR (s); **PNN50** percentage (share) of successive RR (%); **RMSSD** (root mean square of the successive differences), (ms); **SI** stress index (relative units); 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; %); **TP** total power of the heart rate spectrum (ms^2); **RSAI** regulatory systems’ activity indicator (scores).

A risk of sudden cardiac death was calculated based on ECG data and heart rate variability. Nine indicators are considered: heart rate at rest, SDNN, mode amplitude of RR interval histogram, number of steps to zero of autocorrelation function, stress index, duration of **QTc** (see glossary) interval, duration of **QRS** (see glossary) complex, atrial fibrillation/atrial flutter, other high grade arrhythmias/conduction abnormalities. The risk of sudden cardiac death gradation was as follows: none, low, medium, high.

For bioimpedance analysis the TANITA BC-601 (Japan) analyser scales was used to determine body weight and component composition of the body.

To control the overall physical fitness, three exercises were used: push-ups for 1 min (number of times), 90^0 sit-ups for 1 min (number of times), seated hamstring stretch (cm).

Statistical analysis

The statistical analysis of data is performed by means of the licensed IBM SPSS Statistics 22.0, MS Excel. It was defined the indicators of descriptive statistics: arithmetic mean value ($\bar{X}$), standard deviation (SD or ±). 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.

RESULTS

At the beginning of the experiment mass, length and body mass index in the experimental and control groups did not significantly differ from each other ($p>0.05$). After the experiment, significant changes were noted only in the experimental group (Table 2).

After the experiment, the experimental group members had shown a statistically significant decrease in body weight and BMI relative to the initial data. There was also a tendency to reduce the degree of obesity in terms of body mass index among this group (Table 3). If all men were diagnosed with varying classes of obesity before the

Table 2. Changes in anthropometric indicators of obese and overweight men during the experiment.

Variable	Statistical indicator: $\bar{X}$ SD			
	Experimental group (n = 12)		Control group (n = 12)	
	prior to the experiment	at the end of the experiment	prior to the experiment	at the end of the experiment
Body length (cm)	173.33 ±0.06	173.33 ±0.06	172.00 ±0.05	172.00 ±0.05
Body mass (kg)	110.08±15.48	**100.43** ±14.85*	107.84 ±11.59	106.95 ±9.60
BMI (kg/m²)	36.51±4.65	**33.37** ±4.46*	36.49 ±4.06	36.38 ±4.25

*p<0.05

experiment, after 16 weeks of training, three men were found to be overweight (pre-obesity), whose BMI ranged from 27.01 kg/m² to 28.88 kg/m². Six persons were diagnosed with Class I obesity (BMI = 30.41-34.33 kg/m²). Two men had Class II obesity (BMI = 37.70 to 38.77 kg/m²) and one had Class III obesity (BMI = 42.52 kg/m²). In the control group, no significant changes in body weight and BMI were detected (Table 3).

The first examination of the functional state of obese men did not reveal significant differences between 15 indicators of heart rate variability in the experimental and control groups (p>0.05) (Table 4). At the end of the 16-week experiment, significant differences were found in 13 out of 15 HRV indicators in the experimental group and one HRV indicator of the control group (p<0.05, p<0.01). The most pronounced changes in the HRV indicators in the experimental group affected five spectral indicators: TP, LF, HF, VLF, LF/HF and two statistical indicators: SI, RSAI. They significantly differ from the initial data (p<0.05, p<0.01), and the range of changes varies from 24.08% to 191.80%. A change in the spectral indicators after the experiment indicates a change in the types of influence on the heart rate regulation. On average, the group showed a significant decrease in humoral and metabolic effects on heart rate regulation, which occurred due to a decrease in the VLF indicator. After a 16-week experiment among obese men, on average in the group, pronounced sympathotonia was replaced by a moderate predominance of the sympathotonic type of heart rate regulation. Such indicators as TP increased significantly – the increase was 54.6% from the initial data, LF 119.9%, HF 191.8% (p<0.01). Statistically significant decrease in the SI indicator was noted, which on average for the group at the end of the experiment decreased by 61.4 % (p<0.01). The RSAI indicator also significantly decreased, the difference was 2.03 relative units, which corresponds to 62.9 % (p<0.01). Optimal tension of the regulatory systems (RSAI = 0 to 2 scores) was diagnosed in 10 persons, two – moderate tension (RSAI = 3 to 4 scores). The group's LF/HF score decreased by 37.9% on average (p<0.05). Consequently, a 16-week weight loss program with *Muay Thai* components had a positive effect on the cardiovascular system of obese men. They were found to optimize the tension of regulatory systems, reduce humoral and metabolic effects on the heart rate regulation. As well as

Table 3. Change in the degree of obesity before and after the experiment (experimental group n = 12).

Prior to the experiment		At the end of the experiment	
Class of obesity	Number of persons	Class of obesity	Number of persons
Class I	6	Overweight (pre-obesity)	3
		Class I	3
Class II	3	Class I	3
		Class II	0
Class III	3	Class II	2
		Class III	1

Table 4. Changes in heart rate variability of obese men during the experiment.

HRV indicator	Statistical indicator: $\bar{X}$ SD			
	Experimental group (n = 12)		Control group (n = 12)	
	prior to the experiment	at the end of the experiment	prior to the experiment	at the end of the experiment
HR (bpm)	72.71 ±7.53	**65.10** ±4.33*	70.88 ±6.56	70.12 ±5.47
SDNN (ms)	38.00 ±12.42	**44.27** ±6.15*	39.21 ±15.23	39.88 ±4.12
RMSSD (ms)	26.08 ±16.55	28.10 ±10.58	25.34 ±14.55	26.22 ±6.78
PNN50 (%)	47.56 ±5.11	48.47 ±4.38	47.34 ±6.77	47.22 ±10.13
Mo (s)	633.17 ±15.36	**738.44** ±11.16*	658.28 ±24.67	672.45 ±12.44
AMo (%)	38.34 ±6.25	**32.36** ±4.44*	36.88 ±6.33	36.14 ±6.44
SI (relative units)	264.42 ±57.23	**102.00** ±26.20**	258.66 ±48.78	236.18 ±23.48
TP (ms^2)	1479.25 ±1189.23	**2286.65** ±814.34**	1491,87 ±989.4	1461.87 ±433.22
LF (ms^2)	434.45 ±112.45	**955.22** ±110.25**	488.32 ±104.46	510.20 ±88.56
HF (ms^2)	249.33 ±65.35	**727.55** ±110.84**	257.37 ±57.88	337.44 ±48.10
VLF (ms^2)	795.37 ±98.21	**603.88** ±111.12*	746.37 ±101.12	**646.16** ±102.44*
%LF (%)	63.13 ±10.67	**57.12** ±12.12*	65.51 ±8.67	64.14 ±20.20
%HF (%)	36.84 ±11.23	**42.88** ±10.66*	34.44 ±10.44	35.86 ±10.68
RSAI	2.24 ±0.46	**1.39** ±0.45*	1.90 ±0.37	1.79 ±1.24
RSAI (score)	3.23 ±1.68	**1.2** ±0.36**	3.32 ±0.78	3.12 ±1.21

AMo amplitude of the mode of RR**; HF** higher frequency of HRV**; HR** heart rate; **HRV** heart rate variability; **Mo** mode of RR; **LF** low frequency of HRV; **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; *p<0.05, **p<0.01

a decrease in the SI indicator, which also indicates the economization of heart activity. In the control group, no significant changes in HRV indicators were detected at the end of the 16-week experiment. Only one VLF indicator decreased significantly from the initial data, the difference was 100.21 ms^2, which corresponds to 13.43 % (p<0.05) (Table 4).

The analysis of inter-group differences in HRV indicators after 16-week experiment showed that among obese men of the experimental group, 10 of the 15 HRV indicators under study had significantly changed. Pronounced changes were found in two indicators RSAI and SI, the difference was 155.7% and 131.5%, respectively (p<0.01). The HR, Mo, TP, LF, HF, %LF, %HF, LF/HF indicators also significantly changed in the experimental group relative to the control group, varying in the range from 9.33 % to 53.6 % (p<0.05) (Table 5). Pronounced changes were found in two indicators RSAI and SI, the difference was 155.7% and 131.5%, respectively (p<0.01). The HR, Mo, TP, LF, HF, %LF, %HF, LF/HF indicators also significantly changed in the experimental group relative to the control group, varying in the range from 9.33 % to 53.6 % (p<0.05).

The implemented 16-week weight loss program with *Muay Thai* components also had a positive effect on the risk of sudden cardiac death in the experimental group. According to the results of the first examination, a high risk of sudden cardiac death was detected in one obese man, who had seven indicators out of nine. Two participants had an average level of risk of sudden cardiac death (5 to 6 indicators). The remaining nine persons had a low level of risk of sudden cardiac death (1 to 3 indicators). After 16 weeks of training, an examination of this group members showed that seven of them had a low level of a risk of sudden cardiac death. Five persons didn't have it at all. Consequently, the special training program with *Muay Thai* components had a positive effect on the activity of the cardiovascular system, which was reflected in a decrease in the risk of sudden cardiac death of overweight and obese men (Table 6).

Table 5. Indicators of heart rate variability among obese men after the experiment (experimental and control groups).

HRV indicator	Statistical indicator: $\bar{X}$ SD		
	Experimental group (n = 12)	Control group (n = 12)	Magnitude of differences
HR (bpm)	65.10 ±4.33	71.12 ±5.47	**−6.02***
SDNN (ms)	44.27 ±6.15	39.88 ±4.12	4.22
RMSSD (ms)	28.10 ±10.58	26.22 ±6.78	1.88
PNN50 (%)	48.47 ±4.38	47.22 ±10.13	1.25
Mo (s)	738.44 ±11.16	672.45 ±12.44	65.99
AMo (%)	32.36 ±4.44	36.14 ±6.44	**−3.78***
SI (relative units)	102.00 ±26.20	236.18 ±23.48	**−134.18****
TP (ms^2)	2286.65 ±814.34	1461.87 ±433.22	**824.87****
LF (ms^2)	955.22 ±110.25	510.20 ±88.56	**445.02****
HF (ms^2)	727.55 ±110.84	337.44 ±48.10	**390.06***
VLF(ms^2)	603.88 ±111.12	646.16 ±102.44	−42.28
%LF (%)	57.12 ±12.12	64.14 ±20.20	**−7.02***
%HF (%)	42.88 ±10.66	35.86 ±10.68	**7.02***
LF/HF	1.39 ±0.45	1.79 ±1.24	**−0.40***
RSAI (score)	1.22 ±0.36	3.12 ±1.21	**−1.90****

See Table 4 for an explanation of abbreviations see; *p<0.05, **p<0.01

Table 6. Data on the risk of sudden cardiac death of overweight and obese men in the experimental group during the experiment (n = 12).

Test subjects	Risk of sudden cardiac death (level and indicators)	
	prior to the experiment	at the end of the experiment
1	Medium: heart rate at rest; SDNN; mode amplitude of RR interval histogram; stress index; duration of QTc interval	Low: heart rate at rest; duration of QTc interval
2	Medium: heart rate at rest; SDNN; mode amplitude of RR interval histogram; number of steps to zero of autocorrelation function; stress index; duration of QTc interval	Low: duration of QRS complex
3	Low: heart rate at rest; SDNN; mode amplitude of RR interval histogram	None
4	High: heart rate at rest; SDNN; mode amplitude of RR interval histogram; number of steps to zero of autocorrelation function; stress index; duration of QTc interval; duration of QRS complex	Low: SDNN; mode amplitude of RR interval histogram; number of steps to zero of autocorrelation function
5	Low: SDNN; mode amplitude of RR interval histogram	Low: duration of QTc interval
6	Low: number of steps to zero of autocorrelation function	None
7	Low: SDNN; mode amplitude of RR interval histogram; stress index	Low: duration of QTc interval
8	Low: SDNN; stress index	None
9	Low: heart rate at rest; duration of QTc interval; stress index	Low: duration of QTc interval

Test subjects	Risk of sudden cardiac death (level and indicators)	
	prior to the experiment	**at the end of the experiment**
10	Low: SDNN; mode amplitude of RR interval histogram	None
11	Low: mode amplitude of RR interval histogram; number of steps to zero of autocorrelation function; duration of QTc interval	Low: duration of QRS complex
12	Low: stress index; duration of QTc interval	None

QTc (see glossary); **QRS** (see glossary); **RR** respiratory rate; **SDNN** standard deviation of RR

After 16 weeks of regular running, no significant changes in the risk of sudden cardiac death were observed among obese men in the control group (Table 7).

Some indicators of the component composition of the body significantly changed in relation to the initial data after the experiment in the experimental group. No statistically significant changes were found in the control group. Among the experimental group members, the percentage of body fat significantly decreased, the difference was 12.35% relative to the initial level ($p<0.05$). The percentage of fat in the limbs and torso also decreased, the change was in the range from 7.30 to 11.66 % ($p<0.05$) (Table 8).

Table 7. Data on the risk of sudden cardiac death among obese men in the control group during the experiment (n = 12).

Test subjects	Risk of sudden cardiac death (level and indicators)	
	prior to an experiment	**at the end of an experiment**
1	Low: heart rate at rest; SDNN; stress index	Low: heart rate at rest; stress index
2	Low: mode amplitude of RR interval histogram; duration of QTc interval	Low: duration of QRS complex; number of steps to zero of autocorrelation function
3	Low: heart rate at rest; number of steps to zero of autocorrelation function; mode amplitude of RR interval histogram	Low: heart rate at rest; stress index
4	Low: heart rate at rest; stress index; duration of QRS complex	Low: mode amplitude of RR interval histogram; number of steps to zero of autocorrelation function
5	Medium: SDNN; duration of QRS complex; duration of QTc interval; mode amplitude of RR interval histogram; number of steps to zero of autocorrelation function	Medium: SDNN; duration of QTc interval; mode amplitude of RR interval histogram; number of steps to zero of autocorrelation function
6	Medium: number of steps to zero of autocorrelation function; SDNN; duration of QRS complex; duration of QTc interval; number of steps to zero of autocorrelation function	Medium: heart rate at rest; stress index; SDNN; mode amplitude of RR interval histogram
7	Low: SDNN; mode amplitude of RR interval histogram; stress index	Low: duration of QTc interval; SDNN
8	Low: SDNN; stress index	Low: heart rate at rest
9	Low: heart rate at rest; duration of QTc interval; stress index	Low: duration of QTc interval

Test subjects	Risk of sudden cardiac death (level and indicators)	
	prior to an experiment	**at the end of an experiment**
10	Medium: SDNN; mode amplitude of RR interval histogram; number of steps to zero of autocorrelation function; duration of QTc interval	Medium: heart rate at rest; stress index; SDNN; mode amplitude of RR interval histogram
11	Low: mode amplitude of RR interval histogram; number of steps to zero of autocorrelation function; duration of QTc interval	Low: duration of QRS complex
12	Medium: stress index; duration of QTc interval; heart rate at rest; mode amplitude of RR interval histogram	Low: stress index; duration of QTc interval; heart rate at rest; mode amplitude of RR interval histogram

QTc (see glossary); **QRS** (see glossary); **RR** respiratory rate; **SDNN** standard deviation of RR

Table 8. Changes in the component composition of the body of overweight and obese men during the experiment.

Indicator		Statistical indicator: $\bar{X}$ SD			
		Experimental group (n = 12)		**Control group (n = 12)**	
		prior to the experiment	**at the end of the experiment**	**prior to the experiment**	**at the end of the experiment**
Body weight (kg)		110.08 ±15.48	**100.43** ±14.85*	107.84 ±11.59	106.95 ±9.60
Body muscle mass (kg)		69.58 ±6.71	71.22 ±9.11	69.89 ±6.92	69.34 ±7.54
Body fat content (%)		33.43 ±4.42	**29.30** ±4.68*	32.93 ±4.11	32.80 ±3.78
% fat content	Right hand	28.89 ±4.22	**26.42** ±4.48*	29.20 ±4.48	28.76 ±44.28
	Left hand	30.88 ±5.28	**27.28** ±4.55*	30.68 ±5.14	3 0.42 ±4.40
	Right leg	32.76 ±5.52	**30.37** ±4.24*	32.55 ±5.38	32.48 ±4.52
	Left leg	32.38 ±5.16	**29.50** ±4.72*	32.46 ±5.44	32.34 ±5.78
	Torso	35.13 ±4.40	**31.92** ±2.55*	34.86 ±5.10	34.56 ±4.46
Distribution of muscle mass, kg	Right hand	4.37 ±0.58	4.50 ±0.76	4.53 ±0.46	4.47 ±0.52
	Left hand	4.32 ±0.62	4.52 ±0.82	4.22 ±0.58	4.30 ±0.87
	Right leg	12.06 ±1.40	12.60 ±1.74	12.10 ±1.34	12.56 ±1.82
	Left leg	12.21 ±1.42	12.50 ±1.84	12.24 ±1.24	12.34 ±1.66
	Torso	36.62 ±2.88	37.10 ±3.12	36.48 ±3.10	36.82 ±3.44

*p<0.05

Pedagogical testing showed that the experimental group had also shown significant changes in the indicators reflecting strength and flexibility (Table 9). On average, the group's increase in results in three tests ranged from 81.9 % to 150.0 %.

DISCUSSION

The data of experimental studies allow us to conclude that the special 16-week weight loss training program with *Muay Thai* components for obese men can be recommended for reducing BMI, body fat percentage, reducing sudden

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DISCUSSION

The data of experimental studies allow us to conclude that the special 16-week weight loss training program with *Muay Thai* components for obese men can be recommended for reducing BMI, body fat percentage, reducing sudden cardiac death, improving the functional state of the cardiovascular system and increasing individual indicators of physical fitness.

Weight loss without physical activity is impossible. Most men, starting from the age of 40, become overweight and obese [3]. This phenomenon is directly related to the lifestyle of men of this age. It is characterized by physical inactivity, bad habits among men (smoking, alcohol consumption), unplanned food intake, and stress [25]. As well as with neuroendocrine rearrangements, gonad malfunctions, accompanied by significant changes in physiological functions [28, 29]. It is especially important for obese men aged 40-60, to choose the right physical activity that will contribute to weight loss. This issue becomes a challenge due to the fact that individuals of this age often do not show much inspiration in performing aerobic exercises in the form of walking, running, or cycling, which negatively affects the regularity of attending such sessions. For men, it is interesting to use a variety of game-oriented tools during workouts [25], as well as striking techniques of various martial arts, which excites the male instinct, the inner ego [26]. Martial arts exercises develop such personal qualities as confidence, determination, will, and patience among men [26]. Therefore, we included components of *Muay Thai* in the weight loss training program for obese men.

We have confirmed the authors' data on the benefits of combined loads for obese men for reducing body weight [13, 20, 21]. Performing combined aerobic and strength loads for 12 weeks improves the activity of the cardiovascular system, leads to a loss of body weight and body fat in men aged 40-60 in comparison with men of the same age, who did not perform any physical activities [20]. We have proved that combined loads, including a continuous contactless performance of striking and defensive *Muay Thai* techniques for 30 minutes (aerobic module), a performance of strength exercises (strength module), an execution of "18 forms of Taiji-qigong" complex and meditation in the last part are more effective for weight loss than running 3 times a week for 45 min at 50-70 % of maximum heart rate. Our studies have confirmed the data that aerobic exercises aimed at reducing body weight can reduce heart rate indicators [14, 39].

The duration of the training cycle and the type of physical activity is of great importance when planning physical activity for reducing the body weight of obese men. Experts had studied various types of programs for obese men aged 40-60. Aerobic training at home for 3 months was ineffective [14]. A period of 12 months of daily walking exercises for overweight and moderately obese individuals to reduce body weight and body fat proved to be effective [19]. A 4-week aerobic cyclic training program did not lead to weight loss, but it did reduce the fatty liver tissue of obese individuals [16]. The use of martial arts during workouts of overweight and obese women for 12 weeks did not lead to a decrease in body weight, BMI, but helped to reduce fat-free mass and muscle mass in the body [36]. Women trained for 60 minutes three times a week. In the main part of the training session, which lasted

Table 9. Changes in physical fitness indicators of overweight and obese men during the experiment (experimental group n = 12).

Test	Statistical indicator: $\bar{X}$ SD	
	prior to the experiment	at the end of the experiment
Push-ups for 1 min (number of times)	11.5 ±6.14	**20.91** ±5.51*
90^0 sit-ups for 1 min (number of times)	9.33 ±6.69	**21.83** ±10.96*
Seated hamstring stretch (cm)	3.28 ±2.91	**12.50** ±6.37*

40 minutes, women performed a wide range of punches, kicks, elbows and knee strikes, blocks and their combinations [36]. Compared to the above-mentioned studies, our experiment showed a more pronounced efficiency from workouts. Since the workouts of men under our program for 16 weeks allowed us to reduce body weight, BMI, body fat percentage in general, as well as in the upper and lower extremities.

In obese men, there is a moderate or pronounced strain on regulatory systems, high SI values, high heart rate in rest, cardiac arrhythmia, humoral and metabolic influences on the heart rate regulation, and a sharp predominance of sympathotonia. All of these factors are risks of sudden cardiac death. However, in the scientific literature, the authors study indicators of blood pressure, heart rate at rest, after workouts [16, 17, 31, 39], however, they did not show the variability of the heart rate in obese men performing physical activities. Indicators of heart rate variability are predictors of sudden cardiac death. Our research showed that the special training program with *Muay Thai* components for obese men had reduced the risk of sudden cardiac death in all 12 men taking part in the experiment. It had increased the level of the functional state of the cardiovascular system by eliminating cardiac arrhythmias, reducing the tension of regulatory systems, reducing SI indicators, and shifting the type of vegetative regulation of the heart rate towards parasympathotonia.

CONCLUSIONS

The study showed a positive effect of a training program with *Muay Thai* components on body weight, BMI, body component composition, heart rate variability, the risk of sudden cardiac death, and physical fitness of obese men. Obese men in the experimental group worked out five times a week for 90 minutes for 16 weeks according to a program that included an aerobic module (*Muay Thai* components), a strength module, a “18 forms of Taiji-qigong” complex and meditation. We are recommending this program for obese men in their 40s and 60s who lead a sedentary lifestyle.

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