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The effectiveness of the physical therapy program for patients with metabolic syndrome based on the study of the dynamics of the functional state of the autonomic nervous system and hemodynamic parameters

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Abstract

Purpose: determination of the influence of the physical therapy program on the dynamics of blood pressure, heart rate and vegetative Kerdo index in patients with metabolic syndrome.

Material & Methods: the study was conducted on the basis of the Municipal institution of health care "Kharkiv City Hospital No. 3". 28 young women were under observation, randomly divided into two groups: the main group (MG) – 14 patients and the control group (CG) – 14 patients. The mean age of patients in the MG was 31,49±0,71 years, in the CG – 31,06±0,57 years. The patients of the main group underwent rehabilitation measures according to the author's program of physical therapy, which included a hypocaloric diet with a lipid-lowering orientation (lipid-lowering diet No. 1), the basic principles of which are developed by the American Heart Association, therapeutic massage for patients with alimentary-constitutional obesity; kinesitherapy using elements of sports-oriented aerobics and special physical exercises based on Pilates gymnastics using fitballs and expanders; dosed walking in combination with breathing exercises, taking into account the activity of the autonomic nervous system, for patients in the control group – according to the program used for metabolic syndrome in the indicated medical institution. To identify the effectiveness of the author's program, a comparison was made of *heart rate, arterial tonometry, vegetative Kerdo index* (V.I.) at the beginning and end of the study.

Results: in the determination and analysis of blood pressure, heart rate and vegetative Kerdo index during the second study, we noted the normalization of heart rate, SBP, DBP in women of the main group (p>0,05), in the control group, the dynamics of DBP was statistically insignificant (p>0,05). In women of the main group, the heart rate during the second examination compared with the primary one decreased by 19,8%, the SBP level decreased by 9,1%, the DBP level decreased by 11,0%. In CG patients, the heart rate during the second study decreased by 8.8% compared to the primary one, the SBP level decreased by 5,2%, the DBP level decreased by 3,9% (p>0,05).

Conclusions: comparison of the obtained results of the study showed the normalization of hemodynamic parameters and the tone of the autonomic nervous system, there was also a tendency towards balance of the sympathetic and parasympathetic divisions of the ANS in patients of the main group, in the physical rehabilitation of which therapeutic exercises were applied with the use of regulated breathing exercises, taking into account the tone of the sympathetic or parasympathetic divisions of the autonomic nervous system, which helps to improve the quality of life of patients with metabolic syndrome.

Key words: metabolic syndrome, physical therapy, Kerdo index, autonomic nervous system, blood pressure, heart rate, kinesitherapy.

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Анотація

Ефективність програми фізичної терапії хворих на метаболічний синдром на основі вивчення динаміки функціонального стану вегетативної нервової системи та гемодинамічних показників

Мета: визначення впливу програми фізичної терапії на динаміку показників артеріального тиску, частоти серцевих скорочень і вегетативного індексу Кердо.

Матеріал і методи: дослідження проводилось на базі КЗОЗ "Харківська міська лікарня №3". Під наглядом знаходилися 28 жінок молодого віку, які були довільно розподілені на дві групи: основну групу (ОГ) – 14 пацієнтів і контрольну групу (КГ) – 14 пацієнтів. Середній вік хворих ОГ складав 31,49±0,71 років, КГ – 31,06±0,57 років. Пацієнтам основної групи проводились реабілітаційні заходи за авторською програмою фізичної терапії, яка включала гіпокалорійну дієту з гіполіпідемічною спрямованістю (гіполіпідемічна дієта № 1), основні принципи якої розроблені Американською асоціацією серця, лікувальний масаж для хворих на аліментарно-конституціональне ожиріння; кінезотерапію з застосуванням елементів спортивно-орієнтованої аеробіки та спеціальних фізичних вправ на основі гімнастики Пілатес з використанням фітболів та еспандерів; дозовану ходьбу в поєднанні з дихальними вправами з урахуванням активності вегетативної нервової системи, пацієнтам контрольної групи – за програмою, що застосовується при метаболічному синдромі у зазначеному лікувально-профілактичному закладі. Для виявлення ефективності авторської програми проводилося порівняння показників *частоти серцевих скорочень, артеріальної тонометрії, вегетативного індексу Кердо* (V.I.) на початку та наприкінці дослідження.

Результати: при визначенні та аналізі артеріального тиску, частоти серцевих скорочень і вегетативного індексу Кердо при повторному дослідженні ми відзначили нормалізацію ЧСС, САТ, ДАТ у жінок основної групи ($p<0,05$), в контрольній групі динаміка ДАТ була статистично незначущою ($p>0,05$). У жінок ОГ ЧСС при повторному обстеженні в порівняні з первинним зменшилась на 19,8%, рівень САТ зменшився на 9,1%, рівень ДАТ зменшився на 11,0%. У хворих КГ ЧСС при повторному дослідженні в порівняні з первинним зменшилась на 8,8%, рівень САТ зменшився на 5,2%, рівень ДАТ зменшився на 3,9% ($p>0,05$).

Висновки: порівняння отриманих результатів дослідження показало нормалізацію гемодинамічних показників та тонусу вегетативної нервової системи, також спостерігалась тенденція до врівноваженості симпатичного і парасимпатичного відділів ВНС у хворих основної групи, в фізичній реабілітації яких були застосовані лікувальна гімнастика з застосуванням регламентованих дихальних вправ з урахуванням тонусу симпатичного або парасимпатичного відділів вегетативної нервової системи, що сприяє підвищенню якості життя хворих на метаболічний синдром.

Ключові слова: метаболічний синдром, фізична терапія, індекс Кердо, вегетативна нервова система, артеріальний тиск, частота серцевих скорочень, кінезотерапія.

Introduction

Metabolic syndrome is a significant clinical and epidemiological problem in the population of industrialized countries. Data from epidemiological studies regarding the metabolic syndrome are not optimistic. Observations made by scientists and clinicians around the world confirm that today there is a growing epidemic of metabolic syndrome. Its frequency in populations depends on belonging to an ethnic group, age, and gender (Kalmykova et al., 2021)

Today, metabolic syndrome is one of the main problematic issues in the field of public health in many countries of the world. The frequency of metabolic syndrome among the population is high. Previously, metabolic syndrome was considered a disease of older people, however, today the percentage of young people with this pathological condition has increased (Shaposhnikova et al., 2020).

An important role in the development of the metabolic syndrome is given to genetic predisposition, excessive consumption of high-calorie foods and reduced physical activity. Back in 1988, Gerald Reaven described the current MS under the name "Syndrome X". According to G. Reaven, insulin resistance can be detected in 25% of people who lead a sedentary lifestyle (Kalmykova et al., 2020; Kalmykova et al., 2021).

In the studies of Korylchuk (2019), Suprunenko (2020), Kalmykova et al. (2021), Skrypnyk et al. (2021), Kalmykova (2023) metabolic syndrome is a combination of abdominal obesity, insulin resistance (IR) or DM-2, atherogenic dyslipidemia, arterial hypertension, disorders of the hemostasis system, endothelial dysfunction and chronic subclinical inflammation. By most definitions, obesity and IR/DM-2 are key components of MS. A decrease in testosterone levels (androgen deficiency) is a new pathogenetically important component of MS in men, since the frequency and severity of androgen deficiency are directly proportional to obesity and impaired carbohydrate metabolism. (Korylchuk, 2019; Suprunenko, 2020). The main etiological factors of the metabolic syndrome are genetic predisposition, excessive intake of fats and lack of exercise (Kalmykova et al., 2021).

In the works of Dorn et al., (1997), Kannel & McGee (1979), Torgerson (2004), Sjöström (2006), much attention is paid to the problems of the formation of the metabolic syndrome in people with overweight

and cardiovascular pathology, which are due to the results of many Buffalo Health Study, Framingham Study, XENDOS, which showed a close relationship between obesity, hypertension and dyslipidemia, as well as due to the high prevalence of metabolic syndrome in more than 30% of the population.

In Ukraine, the prevalence of metabolic syndrome varies from 20 to 35%, and in women it also occurs 2.5 times more often, and the number of patients only increases with age. According to epidemiological studies conducted in our country, about 12% of adolescents aged 12 to 17 are overweight, of which 2,3% are obese, while every third obese adolescent has signs of metabolic syndrome (Kalmykova et al., 2021). According to other sources, metabolic syndrome is diagnosed in half of children with obesity in adolescence. It has been proven that the formation of the metabolic syndrome begins in infancy, long before the manifestation of type 2 diabetes mellitus and coronary heart disease, and for a long time it is almost asymptomatic. In this regard, the metabolic syndrome is beginning to be recognized not only as an important social, but also as a pediatric problem (Kalmykova et al., 2021).)

Kocherha et al. (2021) note that obesity and metabolic syndrome continue to be the focus of attention not only of the world medical community, but of society as a whole, since they are associated with such severe pathologies as type 2 diabetes mellitus, hypertension and coronary heart disease, non-alcoholic fatty liver disease, pancreatic steatosis, infertility, diseases of the musculoskeletal system, obstructive sleep apnea syndrome, oncopathology, which later become the main cause of a deterioration in the quality of life and a decrease in its expected duration in adulthood.

Obesity and insulin resistance are major components of the metabolic syndrome and risk factors for cardiovascular disease. The positive correlation between obesity and insulin resistance is well known from the literature and authors' studies. However, they have another common link in the form of hyperleptinemia (Shchurko et al., 2022). Worldwide, the prevalence of obesity has been steadily increasing over the past 30 years. Hyperleptinemia leads to blocking the suppression of hunger and an increase in food intake, which ultimately leads to obesity. Obese people are also more likely to develop insulin resistance and high triacylglycerol levels, which can lead to the development of numerous chronic diseases, in particular coronary heart disease. Insulin resistance is determined by the insensitivity of tissues to the concentration of insulin that regulates carbohydrate metabolism, as occurs in healthy people (Shchurko et al., 2022).

According to statistics, more than half of the adult population of Ukraine is obese – 20,4% of women and 11% of men (Virstiuk et al., 2020).

Shved et al. (2023) note that the problem of metabolic syndrome and type 2 diabetes mellitus in Ukraine is quite high and amounts to about 20% in the general population and more than 50% in certain social groups (physical inactivity, fast food lovers, smokers, etc.). At the same time, we note that according to the International Diabetes Federation (IDF), in people with metabolic syndrome, the total risk of developing MI in the next 8 years is 30%, mortality from coronary heart disease was 3 times higher and twice the mortality rate compared to patients without metabolic disorders. In patients with type 2 diabetes mellitus, the risk of developing coronary heart disease is 2 times higher, and the risk of mortality from it is 2-4 times higher than in patients without carbohydrate metabolism disorders. Diabetes mellitus is a risk factor for the development of cardiovascular diseases, regardless of age, arterial hypertension, body weight and type of hyperlipidemia, in 2019, about 4,2 million diabetes-related deaths were registered worldwide.

In Ukraine, diabetes ranks third in prevalence after cardiovascular and oncological diseases. Over the past ten years, the prevalence of diabetes mellitus in Ukraine has increased one and a half times, and as of January 1, 2015, 1,198,047 patients were registered in the country, which is about 2,9% of the total population. If we take into account that for every registered case there are two or three cases of undiagnosed disease, then already now we can talk about more than 2-2,5 million patients. In the coming years, according to doctors' forecasts, the number of people with diabetes will only increase. This will be due to type 2 diabetes. Already, the following statistics can be observed: about 85 thousand people suffer from type 1 diabetes in Ukraine, and the rest (90%) are diagnosed with type 2 diabetes (Yuliya, K., & Sergey, K. 2018). According to the International Diabetes Federation, the prevalence of type 2 diabetes in 2019 is estimated at 9,3% (463 million), by 2030 it will grow to 10,2% (578 million), and in 2045 it will be 10,9% (700 million) (Shved et al., 2023).

According to WHO and UNICEF forecasts, by 2030 there will be 2,5 million obese children and adolescents in Ukraine. At this age, overeating can become a serious problem. This condition has negative consequences for the circulatory, hormonal systems, the human musculoskeletal system and the gastrointestinal tract (Snisar et al., 2022).

The social significance of the metabolic syndrome problem is associated with an increase in educational activity among patients, the need to introduce the basic principles of primary prevention of obesity, diabetes mellitus, especially in children and young people, to promote the principles of healthy nutrition, and to increase the role of physical culture and sports. The medical side of the metabolic syndrome problem is associated with improved diagnostics and the emergence of new effective methods of drug correction of the main risk factors that make up the metabolic syndrome (obesity, arterial hypertension, disorders of carbohydrate and lipid metabolism) (Trybrat et al., 2017).

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Material and methods of research

Participants

The study was conducted on the basis of the Municipal institution of health care "Kharkov City Hospital No. 3". 28 young women were under observation, randomly divided into two groups: the main group (MG) – 14 patients and the control group (CG) – 14 patients. The mean age of patients with OH was 31,49±0,71 years, CG – 31,06±0,57 years. In a previous study (Kalmykova et al., 2021), the distribution of MG and CG by comorbidity and manifestation of the metabolic syndrome is shown in Table 1.

Patients of the main group underwent rehabilitation measures according to the author's program of physical therapy, patients of the control group – according to the program used for metabolic syndrome in the specified medical institution.

The studies were carried out in accordance with international documents on the regulation of biomedical research: "Helsinki Declaration" adopted by the General Assembly of the World Medical Association "on the" ethical principles of medical research involving a person as a subject" (World Medical Association, 2013); "Universal Declaration on Bioethics and Human Rights" (UNESCO, 2005); "Convention for the Protection of Human Rights and Dignity of the Human Being with regard to the Application of Biology and Medicine" adopted by the Council of Europe (1997).

Methods

Determination of heart rate was carried out by palpation of the pulse on the radial artery, with auscultation of the heart at rest, at the beginning, inside and at the end of kinesiotherapy classes according to the generally accepted method. *Arterial tonometry* was performed according to the generally accepted method using a BP AGI-80 membrane tonometer (manufactured by Microlife, Switzerland). The values of systolic and diastolic pressure were determined.

To study the state of the autonomic nervous system, the determination of the *autonomic Kerdo index* (V.I.) (Kerdo, 1966; Kalmykova et al., 2018; Kalmykov et al., 2023) was used, which made it possible to register relatively small changes in autonomic activity.

When the autonomic tone shifts towards sympathicotonia, the diastolic pressure drops, the pulse rate increases, the diastolic pressure/heart rate (d/p) ratio becomes less than 1. With parasympathicotonia, the diastolic pressure increases, the heart rate decreases, the d/p ratio becomes greater than 1. With parasympathicotonia, diastolic pressure increases, the heart rate decreases, the d/p ratio becomes greater than 1. If the deviation from the average value of 1 of the d/p value, determined in a particular case, is multiplied by 100, then we will get any positive or negative integer – "vegetative index". It is calculated according to formula (1):

$$V.I. = (1 - d/p) \times 100, \quad (1)$$

where V.I. – Kerdo vegetative index,
d/p – diastolic pressure / heart rate ratio.

According to this formula, if, for example, d/p=1, i.e. coincides with the average value, then V.I.=0. If less than 1, then V.I. positive – means a shift in the autonomic tone in the direction of sympathetic predominance, if more than 1, then V.I. negative – in the direction of the parasympathetic. It is believed that in a healthy person in a state of eutonia, it is equal to ±0.15, that is, the sympathetic and parasympathetic divisions of the ANS are in a state of dynamic equilibrium. With the predominance of the sympathetic tone, the index increases, and with the predominance of the parasympathetic tone, it decreases and becomes negative. With moderate shifts in the activity of departments V.I. is within ±(0,15-0,3), with expressive – ±(0,3 and more).

An estimate of the calculation of the Kerdo index is

Table 1. Distribution of patients in the main and control groups according to comorbidities and manifestations of the metabolic syndrome

No. i/o	Manifestations of the metabolic syndrome and comorbidities		Groups of examined patients			
			MG, n=14		CG, n=14	
			Abs.	%	Abs.	%
1.	Diabetes mellitus type 2		14	100	14	100
2.	Hypertension I-II degree		10	71,4	9	64,3
3.	Neurocirculatory dystonia for hypertensive type		2	14,3	3	21,4
4.	Obesity	I degree	5	35,7	4	28,6
		II degree	9	64,3	10	71,4
5.	Coronary artery disease. Stable angina I-II functional class		2	14,3	1	7,1
6.	Heart failure I degree		5	35,7	6	42,9
7.	Chronic pancreatitis		3	21,4	2	14,3
8.	Dyskinesia of the biliary system		6	42,9	8	57,1
9.	Chronic pharyngotracheitis		3	21,4	3	21,4
10.	Chronic sinusitis		2	14,3	1	7,1

Table 2. Assessment of the Vegetative Kerdo Index

Indicators	VNS departments
from +16 to +30	sympathicotonia
≥ +31	pronounced sympathicotonia
from −16 to −30	parasympathicotonia
≤ −30	pronounced parasympathicotonia
from −15 to +15	balance between sympathetic and parasympathetic influences

Note: *Normal: −10 to +10%. A positive index value reflects the predominance of sympathetic regulation. Negative – the predominance of parasympathetic regulation.*

presented in Table 2 (Kalmykova et al., 2018).

Procedure

Primary and repeated *determination and analysis of blood pressure and heart rate* were carried out before and after 4 months of using the physical program, as well as during medical supervision during kinesitherapy classes to correct the level of physical activity.

Vegetative Kerdo index was determined in patients with metabolic syndrome at the beginning and end of the study, as well as before the start of physical therapy for timely adjustments in regulated breathing exercises, taking into account sympathetic-, parasympathetic- or eutonia.

The developed rehabilitation intervention technology was implemented in the main group. The proposed tactics of using physical therapy tools differed from standard programs in that it had a comprehensive, interdisciplinary approach to solving the problems of patients with this pathology, the goals of the rehabilitation process were determined taking into account a differentiated approach to the needs of patients with metabolic syndrome. *Short-term goals (for a short period of intervention)* included the normalization of hormonal regulation, lowering blood pressure to normal, reducing the symptoms of endocrine disease, optimizing nutrition, improving daily life and physical activity. *Long-term goals (greater than 3 weeks)* – Maintaining target blood glucose levels is the main goal of treatment. Bring the level of glycemia back to normal, reduce the risk of complications of hypertension (heart attack, stroke, heart and kidney failure, etc.), improve the prognosis of the disease, prolong life. Improve patient well-being, improve quality of life, increase physical activity.

The main goal of the intervention was aimed at normalizing body weight and reducing the manifestations of abdominal obesity, achieving target levels of hyperglycemia compensation, normalizing blood pressure and increasing the tolerance of the cardiovascular system to dosed physical activity. The program of physical therapy of the main group included a hypocaloric diet with a lipid-lowering orientation (lipid-lowering diet No. 1) (Kalmykova et al., 2021), the main principles of which are developed by the American Heart Association (Nishimura et al., 2017; Kalmykova et al., 2020; Members, et al., 2021; Kalmykova et al., 2021; Kalmykova et al., 2021), therapeutic massage for patients with alimentary-constitutional obesity; kinesitherapy; self-study, training walking up the stairs, dosed walking.

The means and methods of intervention were therapeutic exercises for the muscles of the upper limbs and shoulder girdle, neck, torso with elements of sports-oriented aerobics with amplitude, at an average and fast pace (12-16-30 times); special physical exercises based on Pilates gymnastics using fitballs and expanders; exercises for coordination and training of the vestibular apparatus at an average pace, with a maximum amplitude depending on the physical capabilities of the patient (8-10 times); regulated breathing exercises while walking, taking into account the activity of the nervous autonomic system (ANS); rest pauses and relaxation exercises All physical exercises were performed according to the initial positions "sitting on the floor", "standing". When conducting kinesitherapy, the emphasis was on combining different previously learned exercises into a choreographic connection; to change during the lesson of the pace, rhythm, direction and amplitude of movements.

In the kinesitherapy classes, elements of sports-oriented aerobics were used, in which simple series of movements are used, as well as jumping, running on the spot. When constructing the training program, methods of musical interpretation were used, namely, rhythmic music in the style of "foxtrot", "charleston", "tango", Latin American rhythms ("cha-cha-cha", "samba", "rumba"), "disco" , "rock and roll", "break dance", complications (with a change in tempo, rhythm and direction of movement), complications (with a change in the pace, rhythm and direction of movements), blocks with repetition of exercises 4-6 times. Special physical exercises based on Pilates gymnastics (using fitballs and expanders; dosed walking in combination with breathing exercises, taking into account the activity of the ANS).

The advantage of the therapeutic effect of the proposed physical exercises using elements of sports-oriented aerobic rhythmic gymnastics, special physical exercises based on Pilates gymnastics using fitballs and expanders and dosed walking in combination with breathing exercises taking into account the activity of the ANS is:

❖ when performing physical exercises based on Pilates gymnastics and elements of sports-oriented aerobic gymnastics with a multi-vector orientation,

groups of muscles and joints are used that are not involved in the performance of general developmental exercises, resulting in a greater tonic effect, which leads to more stable normoglycemia and normalization of blood pressure;

❖ Pilates gymnastics strengthens the stabilizing muscles that act as a kind of corset, fixes the normal position of the body (posture, internal organs), develops coordination, and improves flexibility. Exercises are performed smoothly without pauses that require high concentration on performance. Pilates exercises are very versatile, and include a large number of muscles at the same time, requiring the correct execution technique, and the number of repetitions can be minimal;

❖ Significant energy costs when performing these physical exercises in combination with a low-calorie diet lead to the normalization of fat and carbohydrate metabolism and normalization of body weight;

❖ The use of physical exercises based on aerobic gymnastics and Pilates gymnastics leads to a stable hypoglycemic effect, does not cause hypoglycemic conditions, and a break in training does not lead to hyperglycemia;

❖ Deep breathing during Pilates exercises and aerobic gymnastics has a direct massaging effect on the pancreas, which leads to stimulation of its endocrine function;

❖ The use of regulated breathing exercises, taking into account the activity of parts of the ANS, contributes to the normalization of blood pressure, body weight and glycemia in patients with metabolic syndrome.

Women of the main group during the day were engaged in *therapeutic walking*. Walking distance – 3-4 km, walking pace – 110-120 steps/min. After 1 month, the walking distance increased to 5-6 km per day, the pace of walking was 120-140 steps/min. During training in walking, patients with MG used walking at a slow pace for 3-5 minutes. every 500–700 m to perform breathing exercises. Breathe while walking through the nose: inhale – two steps; exhale – for 4-6 steps, hold the breath for 1-3 s (to reduce the manifestations of sympathicotonia) or inhale – for 3 steps, hold the breath for 1-3 s, exhale – for 3 steps (to reduce parasympathicotonia).

For a more complete solution of the problems of kinesitherapy, *self-study* was used for patients of the main group using physical exercises for the muscles of the upper limbs and shoulder girdle, neck, torso with elements of sports-oriented aerobics with a full range of initial positions "lying", "sitting", "standing" and "in walking", at an average and fast pace, the number of repetitions – 12-16-30 times; special physical exercises based on Pilates gymnastics using fitballs and expanders; exercises for coordination and training of the vestibular apparatus at an average pace with a full range of motion, the number of repetitions is 6-8 times; regulated breathing exercises while walking, taking into account the activity of the ANS; rest breaks and relaxation exercises.

In order to prevent hypoglycemia, all patients of the main group underwent glycemic control before and after therapeutic exercises, self-study and dosed walking.

In the control group, a physical therapy program was used, which included diet therapy using a hypocaloric diet, therapeutic massage, kinesitherapy, self-study, dosed walking, running, walking, outdoor and sports games. Kinesiotherapy was carried out according to the methods for patients with alimentary-constitutional obesity and diabetes mellitus, with the exception of exercises that are contraindicated in arterial hypertension (static exercises accompanied by an increase in intra-abdominal pressure, torso tilts). Dosed walking was administered to patients in the control group, depending on the severity, comorbidity, age and physical performance of the patient. During the first weeks of walking training, CG patients used a short rest of 2-3 minutes to perform breathing exercises. Distance – 3-4 km, walking pace – 70-90 steps/min. After 1-1,5 months, the walking distance increased to 5-6 km per day, the pace of walking was 70-90 steps/min. Running for 1-2 minutes should be alternated with walking and breathing exercises. Walks should be carried out 2-3 times during the day, starting from 2-3 km and gradually reaching 10 km per day (shallow). During walks, you can alternate slow walking with rapid walking (50-100 m), after which breathing exercises and calm walking are recommended. Gradually, rapid walking is increased to 200-500 m. After training for 2-3 months, jogging is recommended, starting from 25-50 m and gradually increasing to 300-500 m through several runs during the day. Jogging is allowed at any time of the day and in the evening. Independent exercises were carried out independently according to the program 1-2 times a day for 10-15 minutes and included exercises for medium and large muscle groups performed at an average pace with full amplitude in combination with breathing exercises. The number of repetitions of gymnastic exercises is 10-12 times.

The program of physical therapy in patients of both groups depended on the phases of the ovarian-menstrual cycle. During menstruation, static physical exercises associated with straining and increased intra-abdominal pressure were excluded.

The study was carried out in accordance with the research plan "Theoretical and methodological foundations of physical therapy and occupational therapy for organic and functional disorders of the organs and systems of the human body in healthcare practice", 2021-2025 (state registration number 0121U110141)

Statistical analysis

Statistical data processing was carried out using

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the Statistica 13 analysis package. Since all the studied indicators corresponded to the normal distribution law. The significance of the difference was assessed using Student's t-test. Differences that did not exceed the probability level p<0,05 for a given number of degrees of freedom were considered statistically significant.

Results of the study

When determining and analyzing blood pressure, heart rate and vegetative Kerdo index during the initial study, we observed an increase in the level of systolic blood pressure and heart rate in patients of both groups (Table 3)

In women of the main and control groups, arterial hypertension was observed with an increase in *systolic pressure*: 150,28±2,72 and 152,36±2,94 mm Hg, respectively, which confirms the presence of metabolic syndrome in the examined patients (p>0,05). In parallel with this, we found an increase in heart rate in patients of both groups: 90,56±1,43 in patients of the main group and 91,68±1,53 bpm in patients of the control group (p>0,05).

When determining the *vegetative Kerdo index*, we found in the main group 9 people with sympathicotonia, 3 people with parasympathicotonia and 2 people with eutonia. In the control group, 10 people had sympathicotonia, 3 people had parasympathicotonia, and 1 person had eutonia (Figure 1).

The data obtained indicate a shift in the vagal-sympathetic balance towards a weakening of the vagal and dominance of the sympathetic tone in patients of both groups, which is also confirmed by the value of the vegetative Kerdo index (10,21±1,57 in patients MG and 9,37±1.56 in patients CG) (p>0,05) and contributes to the progression of arterial hypertension, hyperglycemia and abdominal obesity.

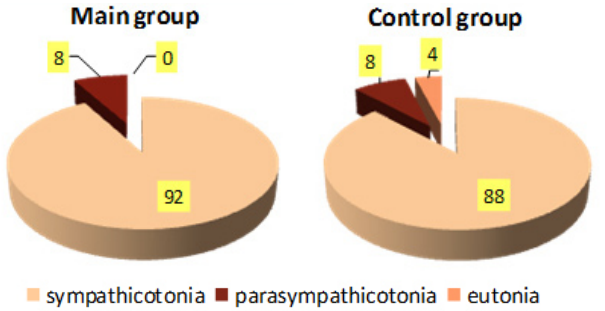

Figure 1. The predominance of the activity of the autonomic nervous system (ANS) in patients of the main and control groups during the primary study (%)

When determining and analyzing blood pressure, heart rate and vegetative Kerdo index during the second study, we noted the normalization of heart rate, SBP, DBP in women of the main group (p<0,05), in the control group, the dynamics of DBP was statistically insignificant (p>0,05).

In women of the main group, the heart rate during the second examination compared with the primary one decreased by 19,8%, the SBP level decreased by 9,1%, the DBP level decreased by 11,0%. In CG patients, the heart rate during the second study decreased by 8,8% compared with the primary one, the SBP level decreased by 5,2%, the DBP level decreased by 3,9% (p>0,05) (Table 4).

Comparing the performance of the cardiovascular system in patients of the main and control groups, we came to the conclusion that during the

Table 3. Hemodynamic parameters and Kerdo index of patients in the examined groups during the primary study (M±m)

Indicators	Norm	Groups of examined patients		t	p
		MG, n=14	CG, n=14		
Heart rate, bpm	60-84	90,56±1,43	91,68±1,53	0,54	>0,05
SBP, mm Hg	100-139	150,28±2,72	152,36±2,94	0,52	>0,05
DBP, mm Hg	60-89	81,60±2,39	83,48±2,56	0,54	>0,05
Kerdo index, c. u.	0±0,15	10,21±1,57	9,37±1,56	0,38	>0,05

Table 4. Dynamics of hemodynamic parameters in patients of both groups during the primary and second study (M±m)

Indicators	Norm	Research periods		t	p
		Primary study	Second study		
Main group (n=14)					
Heart rate, bpm	60-84	90,56±1,43	72,60±1,54	8,57	<0,01
SBP, mm Hg	100-139	150,28±2,72	136,56±2,23	3,90	<0,05
DBP, mm Hg	60-89	81,60±2,39	72,60±1,39	3,26	<0,05
Control group (n=14)					
Heart rate, bpm	60-84	91,68±1,53	83,60±1,51	3,76	<0,05
SBP, mm Hg	100-139	152,36±2,94	144,48±2,52	2,03	<0,05
DBP, mm Hg	60-89	83,48±2,56	80,20±1,95	1,02	>0,05

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Table 5. Hemodynamic parameters of patients in the examined groups during a second study (M±m)

Indicators	Norm	Groups of examined patients		t	p
		MG, n=25	CG, n=25		
Heart rate, bpm	60-84	72,60±1,54	83,6±1,51	5,11	<0,05
SBP, mm Hg	100-139	136,56±2,23	144,48±2,52	2,35	<0,05
DBP, mm Hg	60-89	72,60±1,39	80,20±1,95	3,17	<0,05

re-examination in the main group of patients after the application of the author's program of physical rehabilitation, they were better, which indicates a decrease in the manifestations of the metabolic syndrome in patients of the main group (p>0,05) (Table 5).

When analyzing the state of the *ANS,* a statistically significant improvement was observed in indicators characterizing the imbalance of the sympathetic and parasympathetic parts of the ANS. So, during the re-examination in patients of the main group, eutonia was observed in 12 (85,8%), sympathicotonia – in 1 (7,1%), parasympathicotonia – in 1 patient (7,1%).

In patients of the control group, eutonia was observed in 7 patients (50,0%), sympathicotonia – in 5 patients (35,7%), parasympathicotonia – in 2 patients (14,3%) (Figure 2).

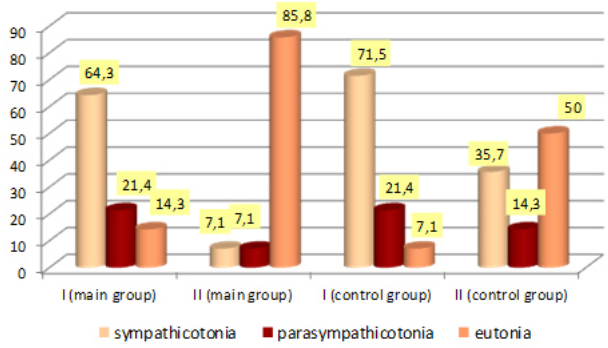

Figure 2. Dynamics of indicators of the state of the autonomic nervous system in patients of the main and control groups (%)

In addition, the level of sympathicotonia according to the Kerdo index in MG patients was at the level of 5,34±1,15, in CG patients it was 6,07±0,86; the level of parasympathicotonia in patients with MG and CG was at the level of –3,05±0,32 and –7,90±3,46, respectively.

Comparison of the results of the study of hemodynamic parameters and the state of the ANS showed a tendency to balance the sympathetic and parasympathetic divisions of the ANS in patients of the main group, in whose physical rehabilitation therapeutic exercises were used with the use of regulated breathing exercises, taking into account the tone of the sympathetic or parasympathetic division.

Discussion

Metabolic syndrome is a multifactorial disease that occurs due to insulin resistance and is accompanied by abnormal deposition of adipose tissue. According to the National Heart, Lung, and Blood Institute and the American Heart Association guidelines, metabolic syndrome is diagnosed when a patient has at least 3 of the following 5 conditions (Nyankovska et al., 2021): fasting glucose ≥100 mg/dL (or therapy to control hyperglycemia); BP ≥130/85 mmHg Art. (or taking antihypertensive drugs); triglycerides (TG) ≥150 mg/dL (or taking medication to control hypertriglyceridemia); high-density lipoprotein (HDL) <40 mg/dl in men or <50 mg/dl in women (or therapy to control low HDL); waist circumference ≥102 cm in men or ≥88 cm in women.

There is no single concept of the metabolic syndrome for males and females, since the formation of the metabolic syndrome in men is directly dependent on the severity of abdominal obesity, and in women such dependence on obesity appears only with the onset of menopause and hypoestrogenemia: 50% of patients with arterial hypertension are women during menopause, the incidence of type 2 diabetes in women 40-50 years old is 3-5%, and over the age of 60 years – 10-20%, that is, carbohydrate metabolism disorders progress with age (Kalmykova et al., 2021). Thus, Palladina (2021) describes metabolic disorders that occur during the menopausal transition or premenopause and end with the onset of menopause, have a direct impact on the health and quality of a woman's entire future life. 35-49% of women develop menopausal metabolic syndrome. This condition is characterized by a violation of carbohydrate tolerance, a rapid increase in body weight and a redistribution of fat with the formation of abdominal and/or visceral type of obesity. In the future, this leads to diabetes, cardiovascular diseases, early disability and premature death. More than half of women (52,4%) develop hypertension, a threefold increase in the risk of coronary heart disease, a sevenfold increase in the risk of stroke. Yes, at the age of 50, the risk of developing coronary heart disease is 46%, and the risk of death from its consequences is 31%.

In men, the leading predictor of metabolic syndrome is abdominal obesity regardless of age; in women, the main starting mechanisms for the formation of metabolic syndrome are diabetes mellitus and menopause. The opinion is expressed that menopause is a natural model of insulin resistance and endothelial dysfunction (Kalmykova et al., 2021). At least 50 complications are associated

with being overweight, including the development of type 2 diabetes mellitus, cardiovascular disease, non-alcoholic fatty liver disease, osteoarthritis, hypertension, sleep apnea, chronic back pain, certain types of cancer, depression, female infertility. In addition, the dependence of body mass index (BMI) and the chances of surviving to 70 years is known. So, for BMI 22.5-30 they make up 80%, for BMI 30-35 – 79%, for BMI 35-40 – 60% and for BMI 40-50 – only 50%. That is why a person who does not control his body weight may not get additional years of life.

According to Sotnikova-Meleshkina et al. (2022) BMI and waist circumference are widely recognized factors that are associated with sex steroid levels and require adjustment as potential risk factors for overweight, BMI or obesity is usually associated with lower serum levels of sex steroid binding globulin, higher height has been associated with lower concentrations of androstenedione, testosterone, free testosterone and sex steroid binding globulin.

According to Kalmykova et al. (2018) the causes of body weight disorders are associated with a violation of the energy balance in the body. It is quite logical to assume that all currently known methods of civilization's struggle with this disease solve one of two problems – they limit the flow of energy into the body or vice versa, contribute to an increase in total energy consumption. In other words, in order to bring the components of fat reserves to physiological norms, it is necessary to implement at least one of two ways. Most experts in determining the etiology of overweight and obesity agree with the opinion that it is multifactorial. At the same time, given that the energy balance is determined not only by the number of calories consumed, but also by the volume of energy expenditure, it is quite logical to assume that, along with eating disorders, a significant contribution to the development of this pathology is made by hypokinesia, which is characteristic of the majority of the modern population.

Turchyna et al. (2022) in their study studied the relationship between Se content, the development of obesity and the formation of metabolic syndrome. What is the correlation between intra-abdominal fat accumulation, Se metabolism and oxidative stress. With excessive consumption of Se, there is an increased risk of developing type 2 diabetes and other metabolic diseases, including hyperlipidemia and non-alcoholic fatty liver disease.

Authors, Carnagarin et al. (2019) note that Sympathetic overdrive contributes to the derangement of glucose metabolism evident in clinical conditions, such as obesity, metabolic syndrome, type 2 diabetes, obstructive sleep apnea, and others. Targeting the sympathetic nervous system directly therefore appears as an attractive therapeutic approach to restore impaired glucose metabolism. Indeed, lifestyle interventions, including healthier diets and exercise, have been shown to exert their beneficial effects at least in part by reducing sympathetic nervous system activity.

Therapeutic measures in the treatment of patients with metabolic syndrome should be aimed at the main links in the pathogenesis of this syndrome, namely, weight loss, achieving an optimal level of blood pressure, achieving metabolic control, and preventing acute and long-term cardiovascular complications (Trybrat et al., 2017)

Virstiuk et al. (2020) note that the search for and justification of effective rehabilitation measures and proper nutrition programs aimed at reducing body weight in overweight and obese people, taking into account the characteristics of their lifestyle and disorders in the body, are urgent tasks of the present. And due to the fact that obese patients cannot perform long-term physical activity, the interval training method should be used. This leads to a gradual increase in the functional capabilities of the body and the coordinated activity of systems that provide oxygen consumption during work. When improving endurance, it is necessary to develop aerobic performance, which has a universal property. As a result, the recovery processes of the body increase and favorable conditions are created for the full manifestation and improvement of anaerobic capabilities.

Conclusion

In the primary study, there was an increase in systolic blood pressure and heart rate in patients in both groups. In women of the main and control groups, arterial hypertension was observed with an increase in systolic pressure, which confirms the presence of the metabolic syndrome in the examined patients ($p>0,05$). In parallel with this, an acceleration of heart rate was found in patients of both groups ($p>0,05$). According to the vegetative Kerdo index in both groups, the shift of the vagal-sympathetic balance prevailed towards weakening of the vagal tone and dominance of the sympathetic tone in patients of both groups, which contributes to the progression of arterial hypertension, hyperglycemia and abdominal obesity. Thus, after the application of a physical therapy program, including a hypocaloric diet with a lipid-lowering orientation (lipid-lowering diet No. 1), the basic principles of which were developed by the American Heart Association, therapeutic massage for patients with alimentary-constitutional obesity; kinesitherapy using elements of sports-oriented aerobics and special physical exercises based on Pilates gymnastics using fitballs and expanders; dosed walking in combination with breathing exercises, taking into account the activity of the autonomic nervous system, repeated studies in the main group indicate the normalization of hemodynamic parameters and the tone of the autonomic nervous system, which improves the quality of life of patients with metabolic syndrome – blood pressure, heart rate noted normalization of heart rate, SBP , DBP in women of the main group ($p<0,05$), in the control group, DBP dynamics was statistically insignificant ($p>0,05$). In women of the main

group, the heart rate during the second examination compared with the primary one decreased by 19.8%, the SBP level decreased by 9,1%, the DBP level decreased by 11,0%. In patients of the control group, the heart rate during the second study decreased by 8.8% compared with the primary one, the SBP level decreased by 5,2%, the DBP level decreased by 3,9% (p>0,05). When analyzing the state of the ANS in patients of the main group, eutonia was observed in 85,8% of patients, in the control group – in 50,0%.

Author's contribution

Conceptualization, Yu.K., S.K.; methodology, Yu.K., S.K.; check, Yu.K.; formal analysis, Yu.K., S.K.; investigation, Yu.K., S.K.; data curation, Yu.K., S.K.; writing – rough preparation, Yu.K., S.K.; writing – review and editing, S.K., Yu.K.; supervision, Yu.K.; project administration, Yu.K. All authors have read and agreed with the published version of the manuscript.

Conflicts of Interests

The authors declare no conflict of interest.

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