UDK [611.1+615.825/796.015.62]

ISSN (English ed. Online) 2311-6374
2020, Vol. 8 No. 1(75), pp. 34-40

Assessment of the reaction of the cardiovascular system to dosed physical activity of patients with metabolic syndrome under the influence of the use of physical therapy

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Purpose: *study of the reaction of the cardiovascular system to dosed physical activity of patients with metabolic syndrome in the process of applying a physical therapy program.*
Material & Methods: *28 young women with metabolic syndrome took part in the study, CG – 14 women, MG – 14 women. The mean age of the patients with MG was 31,49±0,71 years, and the CG was 31,06±0,57 years. In order to determine and assess the tolerance of the cardiovascular system to dosed physical activity in the examined patients, the Martine-Kushelevsky test was used.*
Results: *analyzed and summarized the results of a study of the reaction of the cardiovascular system to dosed physical activity according to the Martin-Kushelevsky test. According to the initial examination in the main and control groups, the indicator of the quality of the reaction according to the Martine-Kushelevsky test was less than normal, which indicates an unsatisfactory reaction of the cardiovascular system of patients to physical activity. After applying the physical therapy program, LRP increased in the main group from 0,40±0,17 to 0,54±0,01 c. u. (by 35,0%), in the control – from 0,41±0,17 to 0,49±0,12 c. u. (by 19,5%).*
Conclusions: *the analysis of the reaction quality indicators in patients of the main and control groups showed that they were better at repeated examination in the main group of patients after applying the author's physical rehabilitation program.*

Keywords: *metabolic syndrome, Martine-Kushelevsky test, physical therapy, women.*

Introduction

Metabolic syndrome is a pathological condition characterized by the development of abdominal obesity, dyslipidemia, arterial hypertension and impaired carbohydrate metabolism (the phenomenon of insulin resistance) [12; 14; 19; 44; 45]. The main etiological factors of the metabolic syndrome are genetic predisposition, excessive consumption of fats and lack of exercise [1; 32]. From literary sources it is known that in industrialized countries among the population over 30 years of age, the prevalence of this pathology ranges from 14 to 24%. It was established that there are age and gender characteristics of the development of metabolic syndrome. In particular, with age, the proportion of patients with this pathology increases. So, in age groups from 20 to 49 years, metabolic syndrome is more often observed in men aged 50–69 years – almost the same in men and women, and in people over 70 years old – more often diagnosed in women. Older women are more likely to have metabolic syndrome due to menopause. This conclusion is confirmed by the data of a study conducted in the United States among women immigrants from the former USSR. In 25% of women, metabolic syndrome was noted according to the criteria of the National Education Program for Cardiovascular Diseases, and its frequency was higher in postmenopausal women [36].

An important role in the development of the metabolic syndrome is given to a genetic predisposition, excessive consumption of high-calorie foods and reduced physical activity. According to G. Reaven, insulin resistance can be detected in 25% of people with a sedentary lifestyle. [50].

It is generally accepted that the current MS under the name "Syndrome X" was described by Gerald Reaven in 1988 [51]. It is important to emphasize that his main merit lies in the fact that he named the common reason for the development of arterial hypertension (AH) in one patient [23; 26; 35], dyslipidemia with an increase in triglycerides (TG), a decrease in high density lipoproteins (HDL), as well as impaired glucose tolerance (IGT) - insulin resistance [11; 13; 25; 27]. Also in the study of this syndrome, studies can be noted in the 30–40s of A. L. Myasnikov, G. F. Lang [47; 48], and later – P. Avogaro [43], N. Mehnert, N. Kaplan [47] and many other domestic and foreign scientists [8; 45; 54].

The mechanisms of the pathogenetic development of the metabolic syndrome are multifaceted and quite complex, since it is difficult to explain at which pathogenesis link the malfunction of the body occurred and what was primary in the development of pathology, since the so-called vicious circle arises.

A key point in the formation of MS is insulin resistance, which triggers a vicious cycle of symptoms, resulting in severe cardiovascular complications - myocardial infarction, cerebral stroke, and circulatory failure [15]. At the same time, IR does not occur spontaneously, according to modern concepts, the moment initiating both insulin resistance and the entire metabolic cascade is most often obesity, which, in turn, leads to the development of arterial hypertension (AH) [16; 22] and can cause a decrease in the sensitivity of peripheral tissues to insulin and further accumulation of excess body weight [20; 29; 30].

The likelihood of developing AH and any cardiovascular disease in people with overweight is 50% higher than in people with normal body weight, according to the Framingham study [49; 52]. In accordance with WHO criteria, the identification and determination of the degree of excess body weight is

based on the calculation of body mass index. Its standard values are 18.5–24.9 kg·m^{-2}. There is convincing evidence that obesity can be both an independent risk factor and a burdensome moment, which significantly worsens the course and prognosis of arterial hypertension, as well as coronary heart disease (CHD) [17; 37]. It was noted that the risk of developing cardiovascular mortality increases even when the body mass index reaches the upper normal range. According to the results of the Nurses Health Study [41], women with body mass index within the upper normal range (from 23 to 24.9 kg·m^{-2}) had a 2-fold higher risk of developing CHD than their counterparts with body mass index (BMI) of less than 21 kg·m^{-2}. It was established that in patients with arterial hypertension, obesity, the risk of developing coronary heart disease is increased by 2–3 times, and the risk of stroke is 7 times. According to the results of the Framingham study [39; 40, 49; 52], it was noted that both systolic and diastolic blood pressure increased by an average of 1 mm Hg with an increase in body weight by 1 kg.

From the point of view of modern ideas, the pathogenetic mechanisms of the development of the metabolic syndrome are based on the violation of purine, carbohydrate and lipid metabolism. As recent studies have shown, adipose tissue has auto, steam and endocrine function and secrets a large number of substances that have various biological effects that can cause the development of concomitant complications, in particular, insulin resistance [9]. The most studied to date is the tumor necrosis factor (TNF-a) and leptin. Scientists see TNF-a as a mediator of insulin resistance in obesity. It has been proven that leptin in the liver can inhibit the action of insulin on gluconeogenesis by affecting the activity of phosphoenolpyruvate carboxykinase, an enzyme that limits the rate of gluconeogenesis. In adipose tissue, leptin can suppress insulin-stimulated glucose transport. Insulin-mediated glucose utilization is reduced by 30–40% in individuals with overweight by 40%, but not only central obesity, but visceral or intra-abdominal fat localization is of fundamental importance. It should be noted that glucose and insulin are important factors in uric acid homeostasis, and an imbalance of these indicators of carbohydrate metabolism leads to hyperuricemia and hyperuricosuria. Under the influence of hyperinsulinemia, the clearance of uric acid in the proximal tubules of the kidneys decreases, which confirms the relationship of insulin resistance and hyperuricemia. Hyperinsulinemia can also increase the activity of the sympathetic nervous system, which leads to an increase in the level of uric acid in the blood serum. Uric acid crystals cause a macrophage reaction. Activated macrophages express adhesion molecules of pro-inflammatory cytokines (IL-1, IL-2, IL-4, IL-6, IL-8, TNF-a), which contribute to the fibroblast degeneration of kidney interstitial cells with loss of their synthetic function. There is a delay in sodium and water, the volume of circulating blood, total peripheral resistance, activation of the sympathetic nervous system and, as a result, the development of arterial hypertension increase [6; 28; 31].

It is extremely important that in patients with metabolic syndrome there are disorders of carbohydrate and lipid metabolism, increased blood pressure, as well as a high risk of coronary heart disease. Therefore, correction of all major pathogenetic disorders should be carried out [38].

The primary task facing medicine is the timely treatment of the metabolic syndrome, including non-drug and drug methods for the correction of metabolic disorders and obesity, and when choosing drugs it is necessary to take into account their metabolic effects and organ protective effect [10; 14; 18; 24; 60].

Thus, among a large number of works on the problem of rehabilitation in the metabolic syndrome, no therapeutic physical culture methods were found that take into account the presence of the components of the metabolic syndrome (abdominal obesity, hyperglycemia, arterial hypertension), there are conflicting data on methods of monitoring and regulating physical activity in accordance with the state patients, that is, optimal pedagogical control is not carried out during group exercises of physical therapy. In addition, the recommendations on the use of diet therapy, massage and physiotherapy are quite contradictory but not individualized.

Purpose of the study: to conduct, analyze and generalize the results of a study of the types of reactions of the cardiovascular system to dosed physical activity of patients with metabolic syndrome using a Martine-Kushelevsky test in the process of applying a physical therapy program.

Material and Methods of the research

Examination of patients was carried out before the use of physical therapy (initial examination) and 4 months after the introduction of comprehensive physical therapy programs (re-examination).

The examination of patients with metabolic syndrome was carried out on the basis of the Kharkiv City Hospital No. 3 under our supervision, there were 28 young women who were arbitrarily divided into two groups: the main group – 14 patients and the control group – 14 patients. The mean age of patients with MG was 31.49±0.71 years, and that of CG was 31.06±0.57 years. By the number of patients, age, and the presence of concomitant pathology, the main and control groups of women were homogeneous. Patients of the main group underwent rehabilitation measures according to the author's program of physical rehabilitation, to patients of the control group – according to the program, they are used for the metabolic syndrome at the outpatient stage in the specified medical institution.

The studies were conducted in compliance with international documents on the regulation of biomedical research: "Helsinki Declaration" adopted by the General Assembly of the World Medical Association (BMA, 1964, 1975, 1983, 1989, 1996, 2000, 2002, 2004, 2008, 2013) on the "ethical principles of medical research involving a person as a subject "[53]; "Universal Declaration on Bioethics and Human Rights" (UNESCO, 2005) [5]; "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) [42].

In order to determine and assess the tolerance of the cardiovascular system to dosed physical activity in the examined patients, we used the Martine-Kushelevsky test – 20 squats in 30 s [20; 21; 55].

The results of the functional test were evaluated by the following indicators: the degree of increased heart rate (%), changes in systolic and diastolic pressure, the recovery time of the pulse and blood pressure after exercise, the reaction quality index (RQI) was determined, which was calculated by the formula:

$$RQI\ (c.u.) = PP_2 - PP_1 / PS_2 - PS_1,$$

where PP_2 – pulse pressure at the 1st minute of the recovery period;

PP_1 – pulse pressure before the load;

PS_2 – pulse in the 1st minute of the recovery period;

PS_1 – pulse before the load.

Normal RQI = 0.5–1.0 c. u. [21; 55].

Using the Martine-Kushelevsky test, the type of reaction of the cardiovascular system to dosed physical activity was determined:

– *Normotonic* – the pulse increases by 60%, systolic blood pressure increases by 20-40 mm Hg, diastolic blood pressure decreases by 5–15 mm RT. Art. or does not change, the pulse pressure increases, the recovery time of the pulse rate and blood pressure is 2–3 minutes.

– *Hypotonic* – the pulse increases more than 120%, the systolic blood pressure practically does not change, the diastolic blood pressure either decreases or does not change, the pulse pressure does not change, the recovery time of the pulse rate and blood pressure is 3–4 minutes, sometimes longer.

– *Hypertensive* – the pulse reacts as if it were a normotonic type, systolic blood pressure rises to 180–200 mm Hg, diastolic blood pressure rises to 90 mm RT. Art. and above, the pulse pressure rises, the restoration of the pulse rate and blood pressure for 3–4 minutes may not take place.

– *Dystonic* – the pulse reacts like in the normotonic type, systolic blood pressure – like in the normotonic type, diastolic blood pressure drops to 0 (the phenomenon of infinite or zero tone), the pulse pressure rises, the restoration of the pulse rate and blood pressure – 3–4 minutes, may and not take place.

– *Step rise in maximum blood pressure* – the pulse reacts as in the normotonic type of reaction, systolic blood pressure is 2–3 minutes higher than the first, diastolic blood pressure as in the normotonic type of reaction, recovery time is 3–4 minutes or recovery is delayed.

– *Dissociated reactions* – proceed according to the type of so-called "scissors" when a negative phase is observed from one of the indicators (pulse or systolic blood pressure). When the pulse rate decreases with increasing systolic blood pressure, a reaction such as cardiovascular dystonia occurs, and, conversely, in the presence of a negative phase on the part of systolic pressure, a reaction such as cardiovascular dissociation [56; 57].

Results of the research

When determining the type of reaction to dosed physical activity during the initial examination in both groups of people with normotonic type of reaction was not detected (Figure 1).

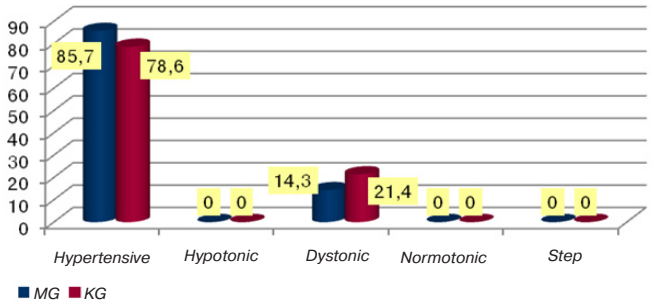

Fig. 1. Characterization of the type of reaction to a Martinine-Kushelevsky test in patients of the main and control groups in the initial study (%)

In both groups the hypertonic type of reaction prevailed. So, in the main group 12 people (85.7%) with a hypertonic type of reaction were identified, with a dystonic type – 2 (14.3%) people; in the control group with a hypertonic type of reaction, 11 (78.6%) people were identified; with a dystonic type – 3 (21.4%) people.

According to the initial examination in the main and control groups of the RQI, the Martin-Kushelevsky test was less than normal, which indicates an unsatisfactory reaction of the patients' cardiovascular system to dosed physical activity (Table 1).

Table 1

Quality indicators of the reaction according to the Martine-Kushelevsky sample of the groups of surveyed in the initial study (M±m)

Indicators	Norm	Groups of surveyed		t	p
		MG, n=14	CG, n=14		
RQI, c. u.	0,5–1,0	0,40±0,17	0,41±0,17	0,57	>0,05

The physical therapy program had a differentiated approach, and included a hypocaloric diet with a lipid-lowering orientation (lipid-lowering diet No. 1) for sick women of the main group, the basic principles of which were developed by the American Heart Association [58; 59]; therapeutic massage according to the methodology of P. B. Efimenko [7] for patients with alimentary-constitutional obesity; medical gymnastics; morning hygienic gymnastics; self-study (SS) dosed walking. Physical exercises were used for the muscles of the upper extremities and the shoulder girdle, neck, torso with elements of sports-oriented aerobics with full amplitude, medium and fast pace; 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 capabilities of the patient; regulated breathing exercises when walking, taking into account the activity of the ANS; rest pauses and relaxation exercises.

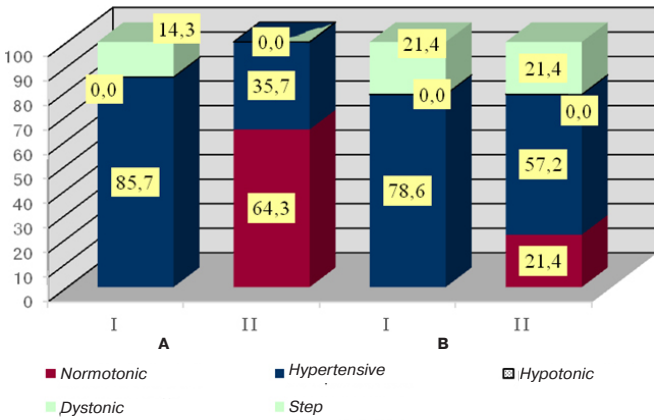

Fig. 2. Types of reaction to dosed physical activity in patients with MG and CG during the primary (I) and repeated (II) studies:
A – main group, B – control group

In the control group of women, a physical therapy program was used, which included diet therapy using a hypocaloric diet, therapeutic massage according to the method of A. F. Verbov [3; 4], medical gymnastics, morning hygienic gymnastics, self-study, dosed walking, running, walking, outdoor and sports games. Therapeutic physical training was carried out according to the methods of S. M. Popov [33; 34], N. A. Beloy [2] for patients with alimentary-constitutional obesity and diabetes mellitus with the exception of exercises,

Table 2

Dynamics of indicators of the quality of the reaction according to the Martin-Kushelevsky test in patients of both groups during the initial and repeated studies (M±m)

Indicators	Norm	Study periods		t	p
		Initial studies	Repeated studies		
Main group (n=14)					
RQI, c. u.	0,5–1,0	0,40±0,17	0,54±0,01	2,35	<0,05
Control group (n=14)					
RQI, c. u.	0,5–1,0	0,41±0,17	0,49±0,12	1,27	>0,05

Table 3

Quality indicators of the reaction according to the Martine-Kushelevsky sample of the examined groups during repeated examination (M±m)

Indicators	Norm	Groups of surveyed		t	p
		MG, n=14	CG, n=14		
RQI, c. u.	0,5-1,0	0,54±0,01	0,49±0,12	3,70	<0,05

are contraindicated in arterial hypertension (static exercises, accompanied by an increase in intra-abdominal pressure, torso).

When determining the *type of reaction to dosed physical activity* during repeated examination, 9 (64.3%) people with normotonic type of reaction, 5 (35.7%) people with hypertonic type of reaction were revealed in the MG. In the control group, upon repeated examination, 3 (21.4%) people were found to have a normotonic type of reaction, 8 (57.2%) of the hypertonic type, 3 people (21.4%) of the dystonic type (Figure 2).

After applying physical therapy programs, RQI increased in the main group from 0.40±0.17 to 0.54±0.01 c.u. (35.0%), in the control – from 0.41±0.17 to 0.49±0.12 c.u. (19.5%) (Table 2).

Analyzing the indicators of the quality of the reaction in patients of the main and control groups, we came to the conclusion that they were better after repeated examination in the main group of patients after applying the author's physical rehabilitation program (Table 3).

Conclusions / Discussion

To analyze the effectiveness of physical therapy in patients with metabolic syndrome, we used the conduct, analysis and generalization of the results of a study of the types of reactions of the cardiovascular system to dosed physical activity using the Martine-Kushelevsky test.

When determining the type of reaction to dosed physical activity during the initial examination in both groups of people with normotonic type of reaction was not found. In both groups the hypertonic type of reaction prevailed. According to the initial examination in the main and control groups of RQI, the Martin-Kushelevsky test was less than normal, which indicates an unsatisfactory reaction of the cardiovascular system of patients with physical activity.

When determining the type of reaction to dosed physical activity during repeated examination, 9 (64.3%) people with normotonic type of reaction, 5 (35.7%) people with hypertonic type of reaction were revealed in the MG. In the control group, upon repeated examination, 3 (21.4%) people were found to have a normotonic type of reaction, 8 (57.2%) of the hypertonic type, and 3 people (21.4%) of the dystonic type. After applying physical therapy programs, RQI increased in the main group from 0.40±0.17 to 0.54±0.01 c.u. (by 35.0%), in the control – from 0.41±0.17 to 0.49±0.12 c.u. (19.5%). Analyzing the indicators of the quality of the reaction in patients of the main and control groups, we came to the conclusion that they were better after repeated examination in the main group of patients after applying the author's physical rehabilitation program.

Conflict of interests. The authors declare that no conflict of interest.
Financing sources. This article didn't get the financial support from the state, public or commercial organization.

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Received: 29.12.2019.
Published: 29.02.2020.

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