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Original Article

Physical exercise application for the correction of carbohydrate metabolism in diabetes mellitus

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Abstract:
Purpose: analyze data on the views of contemporary authors on the use of physical therapy in treatment of type II diabetes mellitus in order to achieve stable compensation of carbohydrate metabolism, to study the features of the parameters of carbohydrate metabolism in patients with type II diabetes mellitus before the beginning of rehabilitation effects, to develop a comprehensive program of physical therapy for patients with type II diabetes mellitus , including kinesiotherapy in combination with individualized diet therapy and to study the effect of an integrated physical therapy program on the parameters of carbohydrate metabolism in patients with type II diabetes mellitus . *Material and methods:* study was based on a clinical and laboratory examination of 40 patients with type II diabetes mellitus, a basic (20 women) and a control group (20 women). Mean age of women in the main group was 51,68±1,25 years, the control age was 51,72±1,44 years. In the basic group of women, a complex program of physical rehabilitation was developed for type II diabetes mellitus, which provided for the use of medical gymnastics and independent exercises, the basis of which were physical exercises with elements of yoga asanas, the patients of the control group were engaged in the method of S.M. Popova (2005), which includes curative gymnastics, morning hygienic gymnastics, self-study. *Result:* use of kinesiotherapy, which is based on physical exercises with elements of yoga asanas, yoga breathing exercises, combined with hypoglycemic nutrition and individually selected hypoglycemic therapy, metformin derivatives lead to a stable compensation for type II diabetes mellitus . *Conclusion:* physical exercises reduce the level of glycemia and insulin requirements, increases blood circulation in the vessels of the heart and other organs and tissues, reduces the body fat and body weight, increases immunity, improves the psychoemotional state of the women.
Key words: physical therapy, physical exercises, elements of yoga asanas, diabetes mellitus

Introduction

Despite the significant advances that the medicine has achieved to date, diabetes mellitus does not cease to be one of the most urgent medical and social problems of modern society. As evidenced by the UN resolution, diabetes mellitus is recognized as one of the most menacing diseases in the world (Pankiv, 2008; Inzucchi, et al. 2012). Today, more than 382 million people with diabetes live on the planet. Without joint and concerted measures to overcome the epidemic of this disease, their number will reach 592 million by 2035 (Kirichenko, Kalmykov, and Kalmykova, 2012). Diabetes mellitus is one of the main causes of blindness, kidney failure, heart attacks, strokes and amputations of the lower extremities. It is estimated that in 2012, 1.5 million deaths were directly caused by diabetes mellitus, and another 2,2 million deaths were due to high blood glucose levels. Almost half of all deaths due to high blood glucose occur before the age of 70 (Pankiv and Bigun, 2012).

The number of patients is progressively increasing all over the world, and Ukraine is no exception, demonstrating a steady trend towards an increase in the incidence and prevalence of diabetes mellitus. Despite the fact that the absolute number of patients with diabetes mellitus in Ukraine decreased due to the geopolitical situation in which our country lives since 2014, diabetes mellitus was, is and will be a disease requiring active medical and national attention (Gulchy, Zamolotova and Sokolova, 2014).

In Ukraine, diabetes mellitus is the third most common after cardiovascular and oncological diseases. Over the past ten years, the prevalence of diabetes mellitus in Ukraine has increased by one and a half times, and as of January 1, 2015, there were 1198047 patients registered in the country, which is about 2,9% of the total population (data excluding statistics of Crimea and the occupied territories of Donetsk and Lugansk regions). If we take into account that for every registered case there are two or three cases of undiagnosed disease, now we can speak about more than 2-2,5 million patients. In the following years, according to the doctors' forecasts, the number of people with diabetes mellitus will only increase. This will be due to type II diabetes mellitus . Already now one can observe such statistics: type 1 diabetes mellitus in Ukraine affects about 85 thousand people, and the rest (90%) are diagnosed with type II diabetes mellitus (Tronko, et al, 2016).

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One way to improve glycemic control is the timely administration of insulin therapy (Nathan, et al, 2009). However, even adequate use of hypoglycemic drugs, the use of metabolites and angioprotectors do not always prevent the development of complications and ensure the maintenance of stable homeostasis. Modern hypoglycemic therapy does not allow to achieve the normalization of all kinds of metabolism in patients with diabetes mellitus (Klebanova, and Balabolkin, 2006; Kalmykov, 2010). Long-term clinical observations of large groups of patients with type II diabetes mellitus showed that 60-70% of newly diagnosed patients can be treated with sulfonylureas with satisfactory glycemic control, 15-20% of patients do not have fast treatment efficacy, and 15-20% of patients , first give in to treatment, a few years after it lose this ability. This phenomenon in the literature was called insulin resistance (Vlasenko, 2010; Pankiv, and Bigun, 2012; Tronko, et al, 2016).

To compensate for diabetes, diet therapy (Hu, FB, et al, 2001; Stavitsky, 2005; Kalmykov 2013), phytotherapy (Kalmikov, 2010; Kalmykov, & Kalmykova, 2016), therapeutic physical culture (Popov, 2005; Kalmykov, 2012) , Yogic gymnastics (Mehta, 2007; Christensen, 2007), Qigong (Klein, Picard, Baumgarden, & Schneider, 2017), Shiatsu massage, therapeutic massage, physiotherapy, spa treatment, occupational therapy (Epifanov, 2006; Kalmykov, 2012; Pustovoit, Kalmykov, and Kalmykova, 2016).

The main mechanisms of action of physical exercises on the human body are neuro-reflex and neuro-humoral mechanisms. There are four main mechanisms of the therapeutic effect of physical exercises on the patient's body: tonic, trophic action, compensation formation and normalization of functions. Muscle load of moderate intensity, achieved by physical exercises for medium and large muscles with a limited number of repetitions, at a slow and medium pace, in alternation with dynamic breathing exercises, promote the consumption of glucose from the blood and its complete cleavage in the muscles, thereby reducing the sugar content in the blood (DeFronzo, et al, 2005; Kalmykov, 2007, 2009). Main objectives of physical rehabilitation in diabetes mellitus are: regulation of glucose in the blood stimulation of tissue metabolism, promotes the utilization of glucose by tissues and reduces the need for insulin; prevention of development of acute and chronic diabetic complications; maintaining normal body weight improving the functional state of the cardiovascular and respiratory systems; expanding the range of the patient's adaptive capabilities to physical activity; improvement of the patient's psychoemotional state; ensuring a high quality of life (Popov, 2005; Kalmykov, 2010).

However, analyzing recent studies and publications, one can note the lack of data on the dosage of physical exercises in type II diabetes mellitus , depending on the level, degree and duration of the reduction of hyperglycemia under physical stress of varying intensity. Reducing the level of glycemia in patients with type type II diabetes mellitus is observed only during and immediately after exercise. All of the above determines the urgency of developing a new comprehensive physical therapy program for patients with type II diabetes mellitus, will promote more sustainable compensation for diabetes mellitus (Rossen, et al, 2015; Cassidy, et al, 2016; Kalmykov, and Kalmykova, 2017).

Material & methods

Material: studies were conducted on the basis of the city polyclinic No. 6 in the Moscow region. Kharkov, 40 young women with diabetes mellitus type II of medium severity were examined, which were arbitrarily divided into two groups: the main group (20 women) and the control group (20 women).

Research methods: analysis and generalization of the results of the primary and repeated study of carbohydrate metabolism was carried out based on the results of determining the fasting glycemia level and after eating, glycosylated hemoglobin carried out in the clinical diagnostic laboratory of polyclinic No.6 on a densitometer scanning device DM 2120 (manufactured by PLC "Solar", Republic of Belarus) with the help of complex diagnostic reagents (manufacturer – HUMAN Gesellschaft fur Biochemica und Diagnostika mbH (Germany)). Current blood glucose monitoring was performed during the exercise of exercise therapy on the Super Glucocard II (GT-1640) (manufactured by ARKRAY Inc. KDK CORPORATION (Japan)) using the GLUCOCARDTM Test Strip II test strips (manufactured by ARKRAY Inc. KDK CORPORATION (Japan). As criteria for compensation of type II diabetes, the fasting blood glucose level was 6,0-6,1 mmol/l, with fasting control – 3,9-5,0 mmol/l, glycosylated hemoglobin – ≤6,1% (Tronko, 2005).

The research design. In the main group of women, a complex program of physical rehabilitation was developed and introduced for type II diabetes, which included the use of medical gymnastics and self-employment based on physical exercises with elements of yoga asanas (Seth Badhasana, Uttangpasan, Bhujangasan, Ardhavakrasan, Matsiendrasan, Pashimotanasan, Shalabhasana, Pavanmuktasana, Supptavirasana, Dhanurasan, Santulanasana, Mandukasana, Padahastasana, shavasana with the duration of each asana 6-8 seconds) and yoga breathing exercises (Pranayama Learn wife), morning hygienic gymnastics. The advantage of the therapeutic effect of the proposed physical exercises in comparison with conventional physical exercises is:

– when performing physical exercises based on dynamic yoga exercises and asanas, yoga breathing exercises are used groups of mucus and joints, are not involved in performing general development exercises, resulting in a greater tonic effect on the central nervous system, leading to more stable normoglycemia; does not cause hypoglycemic conditions, a break in training does not cause hyperglycemia;

– yoga breathing exercises using full breathing and yoga asanas have direct massaging action on the pancreas, leading to stimulation of its endocrine function; prevent occurrence and reduce manifestations of complications of diabetes mellitus from the vessels of the lower extremities;

– performance of physical exercises on the basis of dynamic yoga exercises and asanas, yoga breathing exercises causes normalization of disturbances in the psychoemotional sphere of patients with diabetes, leads to a more complete correction of carbohydrate metabolism.

In the control group, women were treated according to Popov, S.N. (2005), which includes curative gymnastics, morning hygienic gymnastics, self-study.

Women of the main and control groups adhered to the hypoglycemic diet and received individually selected hypoglycemic therapy with metformin derivatives and hypoglycemic dietetics (Stavitsky, 2005; Klebanova, and Balabolkin, 2006).

Statistical analysis

Generalization of the studied characteristics was assessed by mean arithmetic value, standard deviation and error of mean arithmetic. Confidence of differences between mean values was stated by Student's t-criterion. Assessment of statistical hypothesizes based on 5% significance level. For statistical processing of data we used licensed program Microsoft Excel (2010). Statistical analysis of the received results was conducted, considering recommendations on the Microsoft Excel tables usage for computer data analysis.

Results of the study and their discussion

The main criteria for diagnosing the severity of diabetes is determining the level of glycemia in capillary blood on an empty stomach and 2 hours after eating the level of glycosylated hemoglobin ($HbA1_c$). Therefore, we determined the initial values of the above-mentioned indicators. As can be seen from Table 1, the fasting glucose level in the patients of the main and control groups was – 8,85±0,26 and 8,60±0,29 mmol/l, respectively, there was no statistically significant difference between these indices. In women both the main and control groups there was an increase in the level of glycemia after 2 hours after eating (11,47±0,29 and 11,49±0,31 mmol/l, respectively) (p>0,05). These pathological changes confirm the presence of type 2 diabetes mellitus in the examined patients (Byrne, et al, 2017). The level of HbA1c in the patients of the main group and the control group was 9,80±0,21 and 9,97±0,23%, respectively (p>0,05), which indicates a prolonged increase in the concentration of glucose in the blood during the previous 6-12 months and unsatisfactory compensation of diabetes mellitus in the examined patients.

Table 1. Indicators of carbohydrate metabolism before experiment in the primary study of the main (n = 20) and control (n = 20) group of women ($\overline{X} \pm m$)

Indicators	Norm	Surveyed group: main group, (n=20) $\overline{X} \pm m$	Surveyed group: control group, (n=20) $\overline{X} \pm m$	t-criterion of Student	p
Glucose in capillary blood on an empty stomach, mmol/l	3,3-5,5	8,85±0,26	8,61±0,29	0,63	>0,05
Glucose in capillary blood 2 hours after eating, mmol/l	до 7,5	11,47±0,29	11,49±0,31	0,06	>0,05
Glycated hemoglobin($HbA1_c$), %	4,0-6,1	9,80±0,21	9,97±0,23	0,54	>0,05

As a result of application of complex physical rehabilitation programs at the polyclinic stage, the studied parameters of carbohydrate metabolism significantly changed in women of the main and control groups during 4 months. As shown in Table 2, in the main group of women there was a normalization of the parameters of carbohydrate metabolism.

Table 2. Dynamics of carbohydrate metabolism before and after experiment in the main (n = 20) and control (n = 20) group of women($\overline{X} \pm m$)

Indicators	Group	Norm	Before experiment $\overline{X} \pm m$	After experiment $\overline{X} \pm m$	t-criterion of Student	p
Glucose in capillary blood on an empty stomach, mmol/l	Main	3,3-5,5	8,85±0,26	5,98±0,14	9,70	<0,001
	Control		8,61±0,29	6,97±0,19	4,81	<0,05
Glucose in capillary blood 2 hours after eating, mmol/l	Main	to 7,5	11,47±0,29	7,68±0,15	11,59	<0,001
	Control		11,49±0,31	8,73±0,20	7,47	<0,001
Glycated hemoglobin($HbA1_c$), %	Main	4,0-6,1	9,80±0,21	9,07±0,21	2,48	<0,05
	Control		9,97±0,23	9,63±0,24	1,05	>0,05

Thus, in women of the main group, the fasting glycemia index statistically improved: from 8,85±0,26 to 5,98±0,14 mmol/l, glycemia after eating: from 11,47±0,29 to 7,68±0,15 mmol/l, glycated hemoglobin – from 9,80±0,21 to 9,07±0,21% (on 0,73%) (p<0,05). Women of the control group also had a statistically significant

improvement in carbohydrate metabolism: the fasting blood glucose level in the capillary blood decreased from 8,61±0,29 to 6,97±0,19 mmol/l, evel of glycemia after 2 hours. after eating decreased from11,49±0,31 to 8,73±0,20 mmol/l. Level of HbA1c in the control group decreased from 9,97±0,23 to 9,63±0,24% (on 0,34%), and these changes were statistically insignificant (Figure 1).

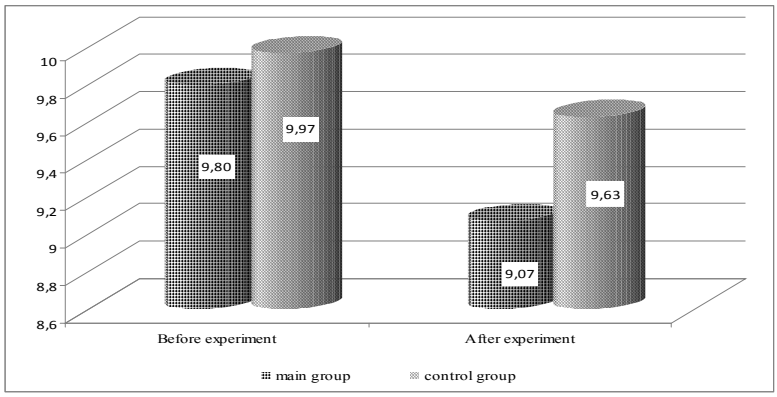

Fig. 1. Dynamics of the level of glycated hemoglobin before and after experimen main (n = 20) and control (n = 20) groups of women

Comparing the indices of carbohydrate metabolism in the patients of the main and control groups, we came to the conclusion that when re-examination in the main group of women after using the author's program of physical rehabilitation they were significantly better (Table 3).

Table 3 Indicators of carbohydrate metabolism after experiment in the second study of the main (n = 20) and control (n = 20) groups of women ($\overline{X} \pm m$)

Indicators	Norm	Surveyed group		t-criterion of Student	p
		main group, (n=20) $\overline{X} \pm m$	control group, (n=20) $\overline{X} \pm m$		
Glucose in capillary blood on an empty stomach, mmol/l	3,3-5,5	5,98±0,14	6,97±0,19	4,26	<0,05
Glucose in capillary blood 2 hours after eating, mmol/l	до 7,5	7,68±0,15	8,73±0,20	4,23	<0,05
Glycated hemoglobin ($HbA1_c$), %	4,0-6,1	9,07±0,21	9,63±0,24	1,75	<0,05

Discussions

Among therapeutic factors in the treatment of diabetes mellitus physical activity is of great importance, it has a multifaceted health-improving effect by increasing the functional activity of various organs and systems of the human body. The main tasks in the treatment of diabetes by means of therapeutic physical training (Epifanov, 2006) are: regulation of blood glucose stimulation of tissue metabolism, promotes the utilization of glucose by tissues and reduces the need for insulin; prevention of development of acute and chronic diabetic complications; maintenance of normal body weight (in patients with type II diabetes, as a rule, there is a decrease in body weight); improving the functional state of the cardiovascular (Kalmikov, 2012) and respiratory systems; expanding the range of the patient's adaptive capabilities to physical activity; improvement of the patient's psychoemotional state; ensuring a high quality of life.

Many authors believe that muscular work (Suseelal, et al, 2016; Sacco, Suda, & Gomes, 2017), especially one that requires endurance, is accompanied by a decrease in insulin levels in the plasma and an increase in glucagon, catecholamine, growth hormone and cortisol (Rossen, 2015; Byrne, 2017). As a result, glycogenolysis and lipolysis, necessary for energy supply of physical activity, are increasing, which is very important for patients with type II diabetes.

Thanks to these physiological mechanisms, regular physical training causes positive changes in the body of patients with diabetes mellitus: a decrease in the level of glycemia and insulin requirements; increased sensitivity of cells to insulin; a decrease in the content of catecholamines in the blood decrease in high blood pressure, the risk of coronary heart disease and other vascular complications due to an increase in the capillary network, improvement of microcirculation, increased blood circulation in the vessels of the heart and other organs and tissues; Reduced adhesion of erythrocytes, accompanied by a lower probability of thrombosis; a decrease in the concentration of triglycerides and an increase in the concentration of high-density lipoproteins; decrease in fat content in the body and, correspondingly, body weight decrease in the risk of osteoporosis, increased immunity and resistance to infection; expansion and economization of the functional capabilities of the organism; improvement of the psychoemotional state and social adaptation of the patient (Sigal, et al, 2007; Yang, et al, 2014).

However, according to the author (Epifanov, 2006), inadequate physical exertion can exacerbate the course of the disease and lead to complications such as hypo- and hyperglycemia, retinal hemorrhage in diabetic retinopathy, acute cardiovascular conditions (myocardial infarction, stroke, hypertensive crisis), there is a high risk of ulceration in the diabetic foot and lower limb injuries in peripheral neuropathy and microangiopathy. In addition, the appointment of means of therapeutic physical culture in diabetes mellitus is limited by the severity of the disease and the presence of complications. Positive action of physical exercises takes place with mild and moderate severity of diabetes mellitus in a state of compensation. In the severe form of diabetes mellitus, exercise should not be prescribed, as this can lead to worsening of the condition, increased levels of glycemia and ketonemia. It should also be borne in mind that inadequate replenishment of energy costs, that is, inadequate and untimely intake of carbohydrates with food before physical exertion with a constant dose of insulin, can cause a hypoglycemic state.

Our studies confirmed the need for correction of glycemia in patients with type 2 diabetes in order to reduce the severity of the disease by applying a comprehensive program of physical therapy, including kinesiotherapy combined with regulated sugar therapy and diet. In the main group of patients, a complex program of physical rehabilitation in type 2 diabetes was developed and introduced, which included the use of therapeutic gymnastics and self-study based on physical exercises with elements of yoga asanas (Seth Badhasan, Uttangpasan, Bhujangasan, Ardhavakrasan, Matsiendrasan, Pashimotanasan, Shalabhasan, Pavanmuktasan, Suptavayrasan, Dhanurasan, Santulanasan, Mandukasan, Padahastasan, Shavasana with the duration of each asana is 6-8 seconds) and yoga breathing exercises (Vrajena-Pranayama), morning hygienic gymnastics, in the main and control groups there were positive changes, namely, the number of complaints decreased, the number of complaints related to the features of the course of type II diabetes mellitus, complications and concomitant illnesses in the study group was significantly less than the control ($p<0,05$).

Conclusions

In the initial study of anthropometric parameters, carbohydrate and lipid metabolism, pathological changes were confirmed in both groups, confirming the presence of type II diabetes mellitus of moderate severity and unsatisfactory compensation of diabetes mellitus in the examined patients; the absence in patients of both groups of progressive weight loss and clinico-laboratory symptoms of decompensated disease testifies to the absence of a deficiency of endogenous insulin.

As a result of the application of complex physical rehabilitation programs for 4 months in patients of the main and control groups, the investigated parameters of carbohydrate metabolism significantly changed: glucose content in capillary blood on fasting and after eating the level of glycated hemoglobin (Kalmykov, 2012; Byrne, Caulfield, & De Vito, 2017). Thus, in patients with OG statistically significant improved fasting glycemia: from 8,85±0,26 to 5,98±0,14 mmol/l, glycemia eating: from 11,47±0,29 to 7,68±0,15 mmol/l, glycated hemoglobin – on 0,73%, which is a positive sign ($p<0,05$). Comparing the parameters of carbohydrate metabolism in the women of the main and control groups, we came to the conclusion that when the second group was re-examined after the author's program of physical rehabilitation, they were significantly better and almost reached the target levels. The study shows that the author's complex physical therapy program, which includes kinesiotherapy combined with hypoglycemic nutrition and individually selected hypoglycemic therapy with metformin derivatives, positively influences the course of type 2 diabetes by improving metabolic processes in the islet apparatus of the pancreas, more efficient metabolic action of the endogenous insulin on cellular receptors and activation of cellular enzymes, and leads to a stable compene diabetes mellitus (DeFronzo, et al, 2005; Masterov, and Kalmykov, 2017; Dixit, Maiya, & Shastry, 2017).

Conflict of Interest

The authors declare that there is no conflict of interests.

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