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Original Article

The use of physical rehabilitation for the recovery of patients with hypertension associated with diabetes mellitus

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Abstract

Problem statement. Hypertension and diabetes frequently occur together, as they share similar risk factors and are components of the metabolic syndrome. The comorbidity of these conditions is among the most common diseases and risk factors for cardiovascular diseases, the prevalence of which increases with age. **Objective**. The study aimed to improve the health of middle-aged patients with hypertension associated with diabetes mellitus through a customized rehabilitation program. **Material and Methods**. The study involved 50 men aged 51.4 ± 4.7 years, diagnosed with arterial hypertension alongside type 2 diabetes mellitus. The participants were divided into two randomized groups (the main group and the comparison group). All subjects provided informed consent before participation. A personalized rehabilitation program was developed for the main group (MG, n = 30), while the comparison group (CG, n = 20) followed standard recommendations for recovery. Blood parameters related to carbohydrate metabolism (glucose, mmol/L; glycated hemoglobin (HbA1c, %); insulin, µU/mL; HOMA index, units) were assessed in all patients. Additionally, lipid profile parameters were measured (cholesterol, mmol/L; triglyceride levels, mmol/L; high-density lipoproteins (HDL), mmol/L; low-density lipoproteins (LDL), mmol/L; very low-density lipoproteins (VLDL), mmol/L; atherogenic index (AI)). Changes in blood pressure (mm Hg) and the risk of premature death from cardiovascular events, as assessed by the SCORE index (%), were also evaluated. **Results**. Implementation of the tailored rehabilitation program, which included health walking, swimming, and diaphragmatic breathing, resulted in a greater reduction in symptoms of hypertension and diabetes in the MG compared to the CG. In the MG, systolic blood pressure decreased by 10.5% ($p < 0.05$). Improvements in carbohydrate metabolism parameters were observed, including a 46.1% decrease in glucose levels, a 31.5% reduction in insulin levels, and a 64.1% decline in the HOMA index ($p < 0.01$). HDL levels increased by 48.0% ($p < 0.05$), while the lipid profile improved, with cholesterol decreasing by 30.3%, LDL by 35.1%, triglycerides by 33.8%, and the atherogenic index decreasing by 41.7% ($p < 0.01$). The SCORE index showed a 47.4% reduction in the risk of premature cardiovascular mortality in the MG ($p < 0.01$). In the CG, patients who followed general lifestyle recommendations showed only a modest decrease in glucose (18.3%), HOMA index (28.6%), and the atherogenic index (29.8%) ($p < 0.05$). **Conclusions**. The results obtained demonstrate that the customized rehabilitation program, incorporating health walking, swimming, and diaphragmatic breathing, had a positive impact on the progression of the disease and significantly improved health. The study supports the implementation of such programs in clinical practice to enhance cardiovascular health and metabolic function in patients with hypertension and type 2 diabetes.

Keywords: **health walking, diaphragmatic breathing, swimming, carbohydrate and lipid metabolism, cardiovascular system**.

Introduction

Arterial hypertension (AH) is a significant global medical and social concern, leading to severe health complications. According to the World Health Organization, approximately 1.13 billion people worldwide suffer

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from AH. This condition is a major contributor to cardiovascular diseases and accounts for 70-75% of strokes and 80-90% of myocardial infarctions. Moreover, AH substantially contributes to heart failure, ischemic heart disease (IHD), cerebrovascular disorders, and kidney dysfunction (Leon B., Maddox T., 2015).

Epidemiological data indicate that individuals with AH face a considerably higher risk of premature disability and mortality. The probability of complications is especially high in patients with coexisting conditions such as dyslipidemia, obesity, diabetes mellitus, smoking, and sedentary lifestyles (Chmyr N. et al., 2023).

Type 2 diabetes mellitus (T2DM) is among the most prevalent metabolic disorders, characterized by disrupted carbohydrate metabolism and insulin resistance. This condition markedly elevates the risk of cardiovascular diseases, doubling the likelihood of IHD and increasing mortality from myocardial infarction by 2 to 4 times. T2DM is a widespread health issue and a leading contributor to disability and premature mortality among working-age individuals. Patients with T2DM frequently develop severe complications, including myocardial infarctions, strokes, kidney failure, vision impairment, and limb amputations (Mills H. et al., 2022).

Research suggests that men, particularly middle-aged individuals, exhibit a higher prevalence of T2DM compared to women. Furthermore, T2DM significantly amplifies the likelihood of cardiovascular diseases, including IHD. Those affected by the condition have twice the risk of developing IHD, with a myocardial infarction mortality rate that is 2 to 4 times higher than in individuals without carbohydrate metabolism disorders (Tramunt B. et al., 2020). The frequent coexistence of hypertension and T2DM is a major health concern. Hypertension is diagnosed twice as often in individuals with diabetes compared to those without, further exacerbating the risk of serious cardiovascular complications. This comorbidity substantially increases the probability of developing severe cardiovascular diseases, including IHD, strokes, and premature death (Przezak A. et al., 2022). The shared pathological mechanisms between hypertension and T2DM, including insulin resistance, lipid metabolism disorders, endothelial dysfunction, and atherosclerosis progression, contribute to their frequent comorbidity. This dual burden represents represents a medical issue and a socioeconomic challenge, increasing healthcare costs and reducing quality of life (Petrie J. et al., 2018).

Persistent hyperglycemia in T2DM negatively impacts vascular integrity, promoting arterial stiffness and accelerating atherosclerotic changes, which subsequently elevate blood pressure levels (Yamazaki D. et al., 2018). Conversely, hypertension may serve as an early indicator of metabolic disturbances, given that obesity, sedentary behavior, and chronic inflammation are common risk factors for both conditions. Individuals with these overlapping disorders often experience significant cardiovascular dysfunction, further complicating disease management (Akalu Y., Belsti Y., 2020).

Patients diagnosed with metabolic syndrome – a cluster of conditions including insulin resistance, obesity, dyslipidemia, and hypertension – face an accelerated progression of cardiovascular diseases. These metabolic abnormalities not only precede the onset of diabetes but also significantly increase the risk of severe cardiovascular events, such as myocardial infarctions and strokes (Li-Zhen Z. et al., 2024).

Hence, early intervention strategies that integrate pharmacological treatment with lifestyle modifications, including structured physical rehabilitation, are crucial for effective disease management (Correia J. et al., 2019).

Physical rehabilitation plays a pivotal role in mitigating the adverse effects of these conditions. Implementing structured exercise programs, such as breathing exercises, swimming, and health walking, has been proven to enhance metabolic processes, optimize lipid levels, improve cardiovascular function, and regulate blood pressure. Additionally, such interventions support weight management and improve overall physical fitness, reducing the likelihood of cardiovascular complications (Korytko Z. et al., 2024). Rehabilitation programs tailored to improving patient health can also minimize reliance on pharmacological treatments and significantly enhance quality of life. Therefore, a fundamental objective in modern medicine is to develop and implement effective therapeutic and rehabilitative strategies for patients with arterial hypertension and diabetes mellitus. Given the underlying disease mechanisms, a comprehensive approach that incorporates physical rehabilitation should be prioritized to prevent complications and enhance health outcomes in this patient population.

The study aims to improve the health of middle-aged patients suffering from arterial hypertension associated with diabetes mellitus through physical rehabilitation methods.

Materials & Methods

The study involved 50 men aged 51.4 ± 4.7 years, diagnosed with arterial hypertension and type 2 diabetes mellitus. Only patients with mild or moderate hypertension (stage I-II) and a confirmed diagnosis of type 2 diabetes were included. All subjects provided informed consent before participation.

The inclusion criteria for the study were: an established diagnosis of hypertensive disease (stage I-II), type 2 diabetes mellitus, and an age range of 36 to 60 years. The exclusion criteria included: age outside the specified range (under 36 or over 60 years), presence of other significant somatic diseases, and alcohol or drug abuse.

Two randomized groups were formed: the main group (MG, n = 30) and the comparison group (CG, n = 20). Both groups received standard hospital treatment and rehabilitative support. The CG patients were provided with general recommendations for home-based rehabilitation exercises, whereas MG patients underwent a customized rehabilitation program. This program included daily dosed health walking (50-60 minutes), diaphragmatic breathing exercises (10 minutes daily), and swimming (twice per week, 30 minutes per session). The exercise intensity was adjusted based on adequacy criteria (Korytko Z. et al., 2019, 2020, 2023). The rehabilitation program lasted for three months.

Patients were examined at the hospital (stage I) and three months later (stage II).

In all patients, morphological characteristics were assessed, including weight (kg), height (cm), and body mass index (BMI, kg/m²) (About Adult BMI).

Blood parameters were analyzed using an automatic hematological analyzer, evaluating carbohydrate metabolism indicators**:** glucose (mmol/L), glycated hemoglobin (HbA1c, %), insulin (µU/mL), and HOMA index (U) **(**Adler A. et al., 2000).

Additionally, lipid profile parameters were measured: cholesterol (mmol/L), triglycerides (mmol/L), high-density lipoproteins (HDL, mmol/L), low-density lipoproteins (LDL, mmol/L), very low-density lipoproteins (VLDL, mmol/L), and atherogenic index (AI, U) **(**Dobiášová M., Frohlich J., 2001**).**

Blood pressure (BP) indicators were recorded, including systolic blood pressure (SBP) and diastolic blood pressure (DBP) (mmHg) **(**Korytko Z., 2020).

The SCORE index (Systematic Coronary Risk Evaluation) was used to assess the risk of premature cardiovascular mortality. Risk classification was as follows: low (<5%) or high (≥5%) **(**SCORE Scale**).**

All study results were tested for normal distribution using the Kolmogorov-Smirnov method, which confirmed a normal distribution.

Statistical analysis was performed using MS Excel 2016 and SPSS 11.5. The Student's t-test**,** Wilcoxon test, and Mann-Whitney test were used to determine the significance of differences between study stages and groups **(**Knihavko V. et al., 2020).

Results

Table 1 shows that the patients in both groups did not differ in any of the indicators at the first stage of the examination (p > 0.05). None of the patients had excess weight. Their BMI was just above the acceptable norm (p > 0.05). The arterial BP of the patients in both groups also did not differ (p > 0.05) and corresponded to moderate hypertension (stage II). The patients did not differ in the SCORE index, which takes into account age, SBP, and cholesterol concentration. The SCORE index of patients in both groups was above 5%, indicating an increased risk of death from cardiovascular diseases within the next 10 years.

Table 1. Morphological and functional indicators of patients in the main group and the comparison group in the first stage of research (M ± m)

Indicators	Group	Statistical indicators			
		$\bar{X}$	m	t	p
Age of patients, years	Main	51,2	4,8	0,257	0,798
	Comparison	49,4	5,1		
Body weight, kg	Main	76,38	5,17	0,416	0,679
	Comparison	73,3	7,8		
Height, cm	Main	173,8	6,71	0,369	0,713
	Comparison	170,3	5,3		
BMI, kg/m^2	Main	25,29	3,2	0,823	0,413
	Comparison	25,36	2,1		
SBP, mmHg	Main	162,2	7,6	0,375	0,709
	Comparison	166,1	7,1		
DBP, mmHg	Main	91,2	8,1	0,018	0,986
	Comparison	91,4	7,6		
SCORE, %	Main	7,39	0,4	1,733	0,087
	Comparison	6,14	0,6		

Note: p > 0.05 indicates statistical non-significance, p < 0.05 indicates statistical significance

Table 2 shows that at the baseline stage of the study, patients in both the experimental (OG) and comparison (CG) groups did not differ in terms of carbohydrate metabolism indicators (p > 0.05).

But at the same time, all patients in both groups had a significant increase in glucose, HbA1c, insulin levels, and an increase in the HOMA index relative to reference values.

Table 2. Carbohydrate metabolism indicators in patients of the main group and the comparison group in the first stage of the study (M ± m)

Indicators	Group	Statistical indicators			
		$\bar{X}$	m	t	p
Glucose, mmol/l	Main	12,8	0,7	1,947	0,055
	Comparison	10,9	0,68		
HbA1c, %	Main	14,7	1,04	1,718	0,090
	Comparison	12,28	0,95		
Insulin, μU/ml	Main	28,6	1,5	0,891	0,376
	Comparison	30,9	2,1		
NOMA Index, units	Main	16,3	1,6	0,679	0,499
	Comparison	14,9	1,3		

Note: p > 0.05 indicates statistical non-significance, p < 0.05 indicates statistical significance

Table 3 shows that patients in both the experimental (OG) and comparison (CG) groups did not differ in terms of lipid profile indicators (p > 0.05). However, in both groups of patients with HT and T2DM, significant and similarly pronounced lipid profile disturbances were found relative to reference values.

Table 3. Lipid profile indicators in patients of the main group and the comparison group in the first stage of the studies (M ± m)

Indicators	Group	Statistical indicators			
		$\bar{X}$	m	t	p
Cholesterol, mmol/l	Main	8,91	0,15	1,040	0,302
	Comparison	8,65	0,2		
HDL, mmol/l	Main	1,05	0,12	0,601	0,550
	Comparison	0,89	0,18		
LDL, mmol/l	Main	4,78	0,35	1,230	0,222
	Comparison	4,29	0,19		
VLDL, mmol/l	Main	0,78	0,05	0,469	0,641
	Comparison	0,81	0,04		
Triglycerides, mmol/l	Main	2,72	0,16	0,291	0,772
	Comparison	2,65	0,18		
Atherogenic index, units	Main	7,74	1,18	0,500	0,619
	Comparison	8,61	1,29		

Note: p > 0.05 indicates statistical non-significance, p < 0.05 indicates statistical significance

After three months, a follow-up examination was conducted for patients in both the experimental group (OG) and the comparison group (CG) to track the effects of the rehabilitation program, which included dosed health walking, swimming, and diaphragmatic breathing.

Figure 1 shows that, at the second stage of the examination, there was a more pronounced trend toward reduced body weight in patients from the OG (by 5.1%), compared to a 2.7% decrease in the CG patients (p > 0.05).

Under the influence of the physical rehabilitation program, SBP decreased by 10.5% in patients from the OG (p < 0.05), whereas in the CG patients, it decreased by 4.8% (p > 0.05).

There was also a tendency to reduce diastolic blood pressure (by 6.5% in the OG patients and by 1.2% in the CG patients, p > 0.05).

Thus, after the rehabilitation program, the blood pressure of the patients in the OG approached physiological norms, averaging around 143/85 mm Hg, while the BP of patients in the CG remained high, averaging around 158/90 mm Hg.

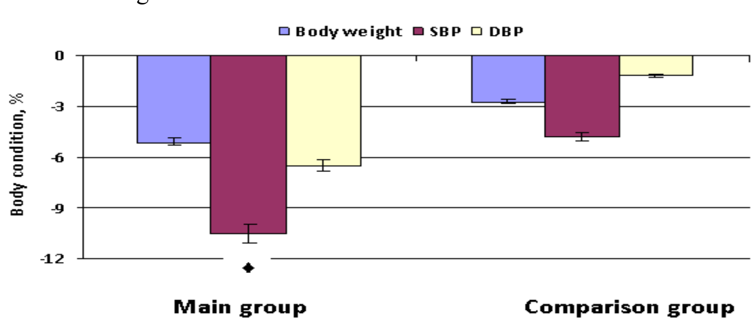

Figure 1. Changes in morphofunctional parameters of patients in the main group and the comparison group at the second stage of examination (%)

Note – ♦ – p < 0.05, SBP – systolic blood pressure, mm Hg, DBP – diastolic blood pressure, mmHg

The reduction in BP contributed to a decrease in the SCORE index, which characterizes the risk of premature death from cardiovascular diseases in the next ten years. In men from both groups, the SCORE index decreased at the second stage of the study (**Figure 2**). In the OG patients, the decrease was more significant (by 47.4%, $p < 0.01$), while in the CG patients, there was only a trend toward a decrease in the SCORE index (by 18.3%, $p > 0.05$).

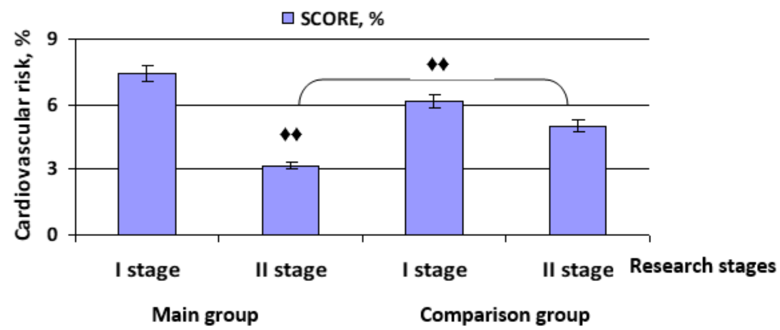

Figure 2. Indicators of the SCORE index of patients in the main group and the comparison group at the I and II stages of the examination (%)

Note – ♦ – $p < 0.05$; ♦♦ – $p < 0.01$

The SCORE index significantly differed between men from both groups at the second stage of the study (after the implementation of the rehabilitation program). In the OG patients, the SCORE index after the rehabilitation intervention was 37.2% lower than in the CG patients ($p < 0.01$).

The rehabilitation program, which included dosed health walking, swimming, and diaphragmatic breathing, also had a positive impact on the carbohydrate metabolism parameters (**Figure 3**).

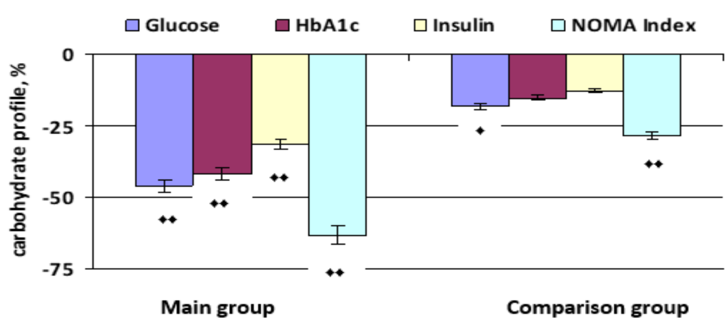

Figure 3. Change in indicators of hydrocarbon metabolism of patients in the main group and the comparison group at the second stage of examination (%)

Note – ♦ – $p < 0.05$; ♦♦ – $p < 0.01$

HbA1c – glycated hemoglobin

The glucose level in the OG patients decreased from 12.8 ± 0.7 mmol/L to 6.9 mmol/L (a decrease of 46.1%, $p < 0.01$), while in the CG patients, the glucose level decreased much less (by 18.3%, $p < 0.05$). At the first stage, the glucose level in the CG patients was 10.9 ± 0.8 mmol/L, and at the second stage, it decreased to 8.89 ± 0.8 mmol/L.

A significant decrease in HbA1c after the rehabilitation program occurred only in patients with OG. In them, HbA1c decreased by 47.7% ($p < 0.01$), while in patients in the comparison group, only a tendency to decrease this indicator was observed (by 15.3%, $p > 0.05$).

The rehabilitation program also had a positive effect on insulin levels. In patients with OG, insulin levels decreased during the study from 28.6 ± 1.5 μU/ml to 19.6 ± 1.9 μU/ml (a decrease of 31.5%, $p < 0.01$). In patients in the comparison group, insulin levels only tended to decrease (from 30.9 ± 0.5 μU/ml to 26.9 ± 2.1 μU/ml, $p > 0.05$).

At the second stage of the study, an improvement in carbohydrate metabolism was observed in both groups of patients. There was a significant reduction in the HOMA index (by 63.1% in the OG patients and by 28.6% in the CG patients, $p < 0.01$). However, the OG patients significantly differed from the CG patients at the second stage in all carbohydrate metabolism parameters ($p < 0.05$).

The proposed rehabilitation program also positively affected the lipid profile in the OG patients (**Figure 4**).

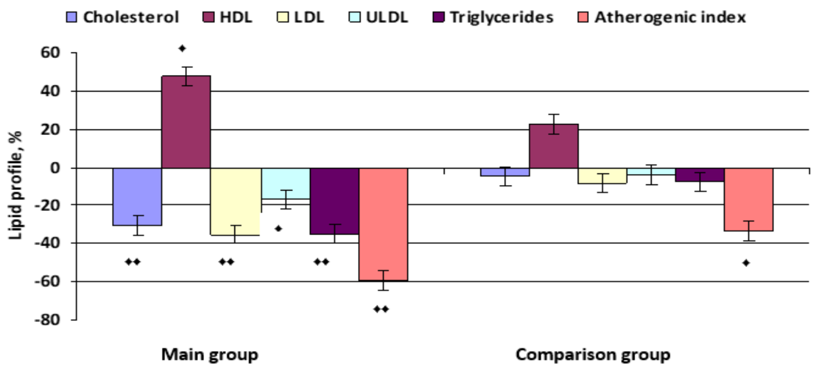

Figure 4. Changes in indicators of the lipid profile of patients in the main group and the comparison group at the second stage of examination (%)

Note – ♦ – $p < 0.05$; ♦♦ – $p < 0.01$

HDL – high-density lipoproteins

LDL – low-density lipoproteins

VLDL – very-low-density lipoproteins

In the OG patients, the levels of cholesterol decreased by 30.3%, LDL by 35.1%, VLDL by 16.7%, and triglycerides by 33.8%. The atherogenic index decreased by 41.7%, and the level of HDL increased by 48.0% ($p < 0.01$). In patients of the CG, all lipid parameters changed significantly less and had only a tendency to decrease ($p > 0.05$). In them, the atherogenic index significantly decreased by 29.1% ($p < 0.05$).

Discussion

Thus, the assessment of the baseline indicators of both study groups showed that the OG and CG groups were sufficiently homogeneous, as at the initial stage (Stage I of the study) they practically did not differ in the duration and course of their disease (both had the same degree of hypertension and type 2 diabetes. Patients from both groups did not differ in key morphological indicators (weight, height, BMI); blood pressure parameters; and had approximately the same disorders in carbohydrate and lipid metabolism.

There were also no differences in the assessment of the risk of premature death from cardiovascular events based on the SCORE scale (7.39 ± 0.4% in the OG and 6.14 ± 0.6% in the CG, $p > 0.05$). However, the SCORE index in both patient groups indicated unfavorable prognoses for cardiovascular diseases. An increase in the SCORE index above 5% indicates the risk of premature death from cardiovascular events within the next 10 years (SCORE scale).

At the initial stage of the study, the main group and the comparison group did not have significant differences in carbohydrate metabolism parameters ($p > 0.05$). However, carbohydrate metabolism parameters in both groups were impaired compared to reference values, which was generally consistent with the clinical features of such patients (Korytko Z. et al., 2021). The elevated levels of glycosylated hemoglobin indicated a high level of blood glucose in patients from both groups over the last three months.

The significantly high levels of insulin in both groups confirmed the presence of insulin resistance, which was also reflected in the HOMA index, which was more than five times above the critical threshold (<3).

According to scientific research, patients with hypertension have higher levels of insulin compared to healthy individuals. A direct correlation between insulin levels in plasma and blood pressure values has been found, confirming its important role in the mechanisms of developing arterial hypertension (Brosolo G. et al., 2021). Insulin resistance is typically associated with type 2 diabetes; however, recent studies report insulin resistance in type 1 diabetes as well (Vladu M. et al., 2017). During insulin resistance, the secretion of the hormone by pancreatic islet cells cannot induce glucose uptake in metabolic tissues, leading to elevated blood glucose and insulin levels. Type 2 diabetes begins with a progressive reduction in insulin action. In this state, the body cannot effectively use insulin to mediate glucose transport into tissues, resulting in the desensitization of insulin receptors. To compensate for insulin resistance, the body produces additional insulin to maintain glucose homeostasis. Insulin resistance is a pathological condition characterized by reduced sensitivity to insulin in target tissues. Elevated insulin levels in the blood due to insulin resistance lead to dyslipidemia, high blood pressure, and altered glucose metabolism (Rochlani Y. et al., 2017).

Most scientists believe that the development of insulin resistance is caused not only by genetic predisposition (Piko P. et al., 2022) but also by several external factors such as obesity, aging, insufficient physical activity, and hyperlipidemia (Brown A., Walker M., 2016).

Thus, patients with diabetes who have blood pressure values near the upper limit of normal should be monitored for the development of hypertension, especially if they have a positive family history of hypertension or phenotypic features of metabolic syndrome. The development of hypertension in diabetic patients is associated with a significant increase in both macrovascular and microvascular risk (Navar A. et al., 2017).

The development of hypertension and diabetes often stimulate each other over time. The progression from normotension to hypertension is characterized by a significant elevation in blood pressure levels. Insulin resistance is a common feature of both prediabetes and prehypertension, particularly in individuals who gain weight over time. Since the development of hypertension in diabetic patients is associated with a significant increase in macrovascular and microvascular risk, efforts should be made to delay or, ideally, prevent the rise in blood pressure (Tsimihodimos V. et al., 2018).

Patients in the main (OG) and comparison (GP) groups had elevated cholesterol levels, indicating a «high risk» of cardiovascular events. All patients also had reduced HDL levels. In OG patients, it was assessed as «conditional risk», and in CG patients, it was assessed as "high risk". In both groups, elevated LDL levels were observed, also assessed as «high risk», as well as elevated triglyceride levels. In addition, the atherogenic index, which is a marker of increased risk of cardiovascular events, was significantly increased (2-3 times) (Kim S. H. et al., 2022).

Given the known positive effects of controlled physical activity on insulin levels and the lipid profile (Yakubovsky T., Korytko Z., 2020; Lin Y. et al., 2022), it can be concluded that the proposed rehabilitation intervention – consisting of dosed health walking combined with diaphragmatic breathing – led to positive changes. This was reflected in both glucose metabolism markers and lipid profiles in the patients of the OG at the second stage of the study, where the results were significantly better compared to the patients of the CG ($p < 0.05$). In both groups, a reduction in diabetes manifestations was observed, as evidenced by decreased levels of glucose, HbA1c, insulin, and the HOMA index. However, these indicators decreased more significantly in the OG patients ($p < 0.01$), while in the CG patients, the changes were smaller ($p < 0.05$).

Additionally, in the patients of the OG, improvements in the lipid profile were noted, including a significant reduction in concentrations of cholesterol, LDL, and triglycerides ($p < 0.01$) as well as an increase in HDL levels ($p < 0.05$). This led to a reduction in the atherogenic index, approaching normal values, and significantly lowered the risk of coronary death among patients in this group.

Thus, the application of the rehabilitation program resulted in a substantial reduction in the manifestations of the primary diseases, as evidenced by the decrease in blood pressure and the optimization of glucose and lipid metabolism parameters. This, in turn, contributed to a lower risk of sudden death from cardiovascular complications. The findings confirm that structured rehabilitation programs lead to significant reductions in hypertension and metabolic risks. Compared to standard recommendations, individualized exercise programs had a greater impact on glucose metabolism and cardiovascular outcomes.

Conclusions

In conclusion, the use of the rehabilitation program in the main group of patients led to a more significant reduction in the manifestations of arterial hypertension compared to the comparison group. Patients in the main group had a more significant reduction in blood pressure and a significantly lower risk of sudden death from cardiovascular diseases, determined by the SCORE scale.

After the rehabilitation intervention, patients in the main group also showed more significant improvements in glucose and lipid metabolism. They experienced a greater reduction in glucose levels, glycated hemoglobin, and improved glucose tolerance, as evidenced by a decrease in the HOMA index. These patients also saw a more significant reduction in risk factors for heart attacks and strokes, which was confirmed by the lowering of triglyceride, cholesterol, low-density lipoproteins, and very-low-density lipoproteins levels, as well as a decrease in the atherogenic index.

Thus, the results indicate the positive impact of the rehabilitation program, which includes dosed health walking, diaphragmatic breathing, and swimming, on the course of the primary disease and the reduction of cardiovascular risks in patients with arterial hypertension associated with diabetes. This supports the effectiveness of the program and its potential recommendation for clinical use. This study highlights the effectiveness of a customized rehabilitation program for managing hypertension and type 2 diabetes**.**

Conflict of interest

The authors declare that there is no conflict of interest.

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