Combined efficacy of low-calorie diets and aerobic training on nutritional status of obese patients with early type 2 diabetes

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Abstract. – OBJECTIVE: The purpose of this study was to evaluate the combined efficacy of low-calorie diets and aerobic training on the nutritional status of obese patients with early type 2 diabetes mellitus.

PATIENTS AND METHODS: 120 consecutive obese patients with early type 2 diabetes were admitted to our hospital between August 2021 and December 2022. The patients enrolled were equally and randomly allocated into the control group (60 cases, given conventional diabetes diet intervention) and the study group (60 cases, given a low-calorie diet intervention combined with aerobic training). The parameters, including the nutritional status, fasting insulin (FINS), Homeostatic Model Assessment for Insulin Resistance (HOMA-IR), blood lipid level, and quality of life, were compared between the two groups.

RESULTS: Before treatment, there were no measurable differences in the levels of fasting blood glucose (FBG), 2-hour postprandial blood glucose (2hPG), glycosylated hemoglobin (HbAlc), albumin (ALB), prealbumin (PA), and hemoglobin (Hb) between the two groups ($p>0.05$), whereas two months after treatment, the FBG, 2hPG, and HbAlc levels were greatly lower, and the levels of ALB, PA, and Hb were significantly higher in the study group than those in the control group ($p<0.05$). Before treatment, no statistically significant differences were found in FINS and HOMA-IR values between the two groups ($p>0.05$). Two months after treatment, however, the study group showed lower FINS and HOMA-IR values as compared to the control group, with statistically significant differences ($p<0.05$). Before treatment, there was no statistically significant difference in the levels of triacylglycerol, total cholesterol, high-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C) between the two groups ($p>0.05$), while the four levels in the study group were significantly lower than those in the control group two months after treatment ($p<0.05$). Similarly, there were no statistically significant differences in scores of physiological, psychological, social, and therapy-related problems between the two groups before treatment ($p>0.05$), whereas the abovementioned scores were evidently higher in the study group than control group two months after treatment ($p<0.05$).

CONCLUSIONS: A low-calorie diet intervention combined with aerobic training exerted good effects in terms of greatly enhancing the nutritional status among obese patients with early type 2 diabetes mellitus, which was deemed appropriate for clinical promotion and implementation.

Key Words:
Low-calorie diet intervention, Aerobic training, Obese patients with early type 2 diabetes, Nutritional status.

Introduction

In recent years, the incidence of diabetes mellitus has shown a substantial upsurge. Recent statistics indicate that China has a diabetic patient population exceeding 40 million individuals, thus occupying the second position globally in terms of prevalence[1]. According to the prediction of the International Diabetes Federation[2], approximately 642 million people worldwide will suffer from diabetes by 2040, of whom 90% to 95% will suffer from type 2 diabetes. If left uncontrolled, the incidence rate of diabetes patients will continue to rise. Obesity is considered as the primary causative factor for type 2 diabetes. The prevalence of obesity in China has reached an alarming rate of approximately 690 million, with a similar proportion of men and women affected. It has been reported[3,4] that nearly 60% of the diabetic population is either overweight or obese. The co-occurrence of diabetes and abnormal lipid metabolism due to obesity can lead to serious complications such as cardiovascular and chronic kidney diseases, thereby significantly reducing the quality of life of affected individuals.

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The current medication options for early type 2 diabetes primarily target glucose metabolism. The onset of early type 2 diabetes is determined by a combination of genetic and environmental factors, where dietary and exercise interventions play a crucial role in the occurrence and progression of both diabetes and obesity[5]. Reduction in calorie intake has been shown[6-8] to positively impact the pathological progression of early type 2 diabetes, while exercise interventions can improve the utilization of sugar by muscles and tissues, leading to better blood sugar control. Aerobic training is an effective exercise modality that promotes glucose uptake by muscles and liver, increases insulin receptor expression and sensitivity, and subsequently reduces blood sugar levels[9]. However, there is limited evidence on the synergistic effect of combining low-calorie diets with aerobic training and its potential role in regulating nutritional status. Herein, the current study was conducted in order to explore the combined effect of low-calorie diets and aerobic training on the nutritional status of obese patients with early type 2 diabetes mellitus.

Patients and Methods

General Information

There were 120 consecutive obese patients with early type 2 diabetes admitted to our hospital between August 2021 and December 2022. The patients enrolled were equally and randomly allocated into the control group by using a random number table. The control group consisted of 21 male and 39 female participants, ranging in age from 22 to 69 years old, with an average age of (46.19±12.78) years. The duration of the disease for this group was between 1 to 6 years, with an average duration of (3.78±1.01) years. In the study group, there were 17 males and 43 females, aged 22-72 years, with an average age of (46.98±13.76) years. The duration of the disease was between 1 to 6 years, with an average duration of (3.87±1.18) years. There was no measurable difference in general information between the two groups of patients (p>0.05). This research protocol was carried out in accordance with the Helsinki Declaration of the World Medical Association.

Selection Criteria

Inclusion criteria

The diagnostic criteria for the early identification of type 2 diabetes have been established in accordance with the Guidelines for the Prevention and Treatment of Type 2 Diabetes in China (2020 Edition)[10]. The diagnosis could be confirmed if any of the following criteria were met: fasting blood glucose (FBG) level >7.0 mmol/L (126 mg/dI), random blood glucose level ≥11.1 mmol/L (200 mg/dI), blood glucose level >11.1 mmol/L (200 mg/dI) 2 hours after the 75 g oral glucose tolerance test (OGTT), or glycosylated hemoglobin (HbAlc) level ≥6.5% (48 mmol/L). Additionally, the individual must demonstrate the ability to effectively collect, comprehend, and utilize online intervention methods, while also providing regular updates on their FPG information. Further, normal organ function and cognitive abilities were required, and the participant must provide informed consent before undertaking any intervention.

Exclusion criteria

Exclusion criteria were alcohol or drug abusers, history of hypothyroidism and mental illness, frequent occurrences of hypoglycemia, breast-feeding women, patients who were already pregnant or had a pregnancy preparation plan in the past year, severe gastrointestinal and other major diseases, type I diabetes or secondary diabetes, patients who were unable to live independently.

Methods

Both groups of patients were given metformin hydrochloride tablets (Jilin Daojun Pharmaceutical Co., Ltd., No.: H22021585) before meals during the intervention process, at a dose of 0.5 g, 3 times a day, and glimepiride tablets (Chongqing Kangkele Pharmaceutical Co., Ltd., No. H20030800) before meals at a dose of 4 mg/d, once a day.

The patients in the control group were given a conventional diabetes diet intervention and were instructed to take 250-300 g staple food (rice, noodles), 150 g meat (chicken, fish, mutton, pork), 300 g sugar-free vegetables every day, with a total calorie of 7,678.23 kJ.

The patients in the study group received a low-calorie diet intervention combined with aerobic training. A low-calorie diet intervention includes controlling the daily diet based on the patient's BMI, such as staple food 150 g/d, meat 100 g/d, low-sugar vegetables 300 g/d, protein 82 g/d, carbohydrates 139 g/d, <30 g/d, with the daily total calorie intake of around 4,598.7 kJ. The patients' BMI level was monitored each time for timely adjustment to the dietary plan. For aerobic training intervention, the main exercise method was brisk walking after meals, which should start 60 minutes after meals and last for 25-50 minutes per session.

The exercise frequency should not be less than 5 days per week. Stretching for 3-5 minutes was encouraged after exercise. Moreover, the exercise intensity was calculated based on age. With the maximum heart rate of the patient=(220-age), the exercise heart rate was 60-70% of the maximum heart rate. The patient should take a brisk walk of 80-100 m/min, 100-140 steps/min, for 8 weeks.

The intervention process during the hospitalization of the above two groups was supervised and completed by the inpatient nursing staff. A WeChat group was established before discharge, and patients were instructed to take daily food photos, and weigh themselves, and provide the photos to the group. After the patients were discharged from the hospital, they were instructed to undergo a follow-up every 2 weeks, for a period of 2 months. It was recommended a monthly telephonic communication be established in order to ascertain the patient's current health status, encourage adherence to the prescribed medication regimen, and promote regular physical activity.

Observation Indicators

The nutritional status levels, FINS, Homeostatic Model Assessment for Insulin Resistance (HOMA-IR), blood lipid levels, and quality of life before and two months after intervention were compared between the two groups.

Nutritional status

Before and 2 months after the intervention, the FBG, 2-hour postprandial blood glucose (2hPG) levels, glycosylated hemoglobin (HbAIc), albumin (ALB), prealbumin (PA), hemoglobin (Hb), and body fat percentage were compared between the two groups. HbAIc levels were measured using the HbAIc analyzer HA-8100, ALB using the bromocresol green method, PA using immunoturbidimetry, and Hb levels using copper sulfate turbidimetry.

FINS and HOMA-IR

Before and 2 months after the intervention, FINS was detected with the application of the Cobase601 fully automatic electrochemical luminescence instrument (Roche, Basel, Switzerland); HOMA-IR= (FINS × FBG)÷22.5.

Blood lipid level

Fasting venous blood measuring 3 mL before and after the intervention was collected before and 2 months after the intervention, then it was centrifuged and sent for inspection. Triacylglycerol, total cholesterol, high-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C) were detected using German Beckmann Dx800 automatic biochemical analyzer and its supporting test.

Quality of life

The Diabetes Specificity Quality of Life (DSQL) scale[11] was used to assess the quality of life before and 2 months after the intervention. The scale contains 27 items in total, reflecting physiological, psychological, social, and therapy-related problems with quality of life. Each item was scored by Likert 5 grade scoring method. As the score increases, the patients' quality of life improves. Moreover, the Cronbach's α coefficient was 0.91, and the internal consistency reliability was set at 0.95.

Statistical Analysis

The statistical analysis was conducted using SPSS software (version 21.0; IBM Corp., Armonk, NY, USA). The measurement data of normal distribution was expressed as mean ± standard deviation (SD), and the comparison of measurement data between the two groups was performed by the *t*-test. The counting data was expressed as a percentage (%), and inter-group comparisons were done using χ^2 tests, with the Chi-square test used for all counting data. Statistical significance was set at <0.05.

Results

Comparison of Nutritional Status

Before treatment, there were no measurable differences in the levels of FBG, 2hPG, HbAIc, ALB, PA, and Hb between the two groups ($p>0.05$), whereas two months after treatment, the FBG, 2hPG, and HbAIc levels were greatly lower, and the levels of ALB, PA, and Hb were significantly higher in the study group than those in the control group ($p<0.05$), as shown in Table I.

Comparison of FINS and HOMA-IR Levels

Before treatment, no statistically significant differences were found in FINS and HOMA-IR values between the two groups ($p>0.05$). Two months after treatment, however, the study group showed lower FINS and HOMA-IR values as compared to the control group, with statistically significant differences ($p<0.05$). (Table II)

Table I. Comparison of nutritional status ($\bar{\chi}$±s).

Parameter	Time	Study group (n=60)	Control group (n=60)	t	p
FBG (mmol/L)	Before therapy	8.46±1.38	8.39±1.41	0.275	0.784
	2 months after therapy	6.18±1.53	7.32±1.67	-3.899	<0.001
2hPG (mmol/L)	Before therapy	13.21±1.67	13.17±1.73	0.129	0.898
	2 months after therapy	8.65±1.65	10.08±1.76	-4.591	<0.001
HbAIc (n)	Before therapy	8.54±1.09	8.48±1.17	0.291	0.772
	2 months after therapy	6.81±1.16	6.98±1.21	-0.786	0.433
ALB (g/L)	Before therapy	26.01±2.18	27.65±3.32	-3.198	0.002
	2 months after therapy	39.76±2.76	32.18±3.76	-0.992	0.323
PA (g/L)	Before therapy	0.18±0.05	0.19±0.06	-2.739	
	2 months after therapy	0.34±0.06	0.26±0.07	6.721	<0.001
Hb (g/L)	Before therapy	96.27±9.03	97.39±10.36	-0.631	0.529
	2 months after therapy	119.67±10.76	106.23±10.93	6.788	<0.001
Body fat percentage (%)	Before therapy	28.87±3.29	28.79±3.34	0.132	0.895
	2 months after therapy	23.01±3.07	25.38±3.76	-3.782	<0.001
BMI (kg/cm^2)	Before therapy	27.78±3.02	27.84±3.17	-0.106	0.916
	2 months after therapy	22.76±3.43	24.39±3.56	-2.554	0.012

FBG, fasting blood glucose; 2hPG, 2-hour postprandial blood glucose; HbAIc, glycosylated hemoglobin; ALB, albumin; PA, prealbumin; Hb, hemoglobin; BMI, body mass index.

Table II. Comparison of FINS and HOMA-IR values ($\bar{\chi}$±s).

Parameter	Time	Study group (n=60)	Control group (n=60)	t	p
FINS (mU/L)	Before therapy	17.98±2.76	17.89±2.98	0.172	0.864
	2 months after therapy	12.27±2.31	14.87±2.67	-5.704	<0.001
HOMA-IR (%)	Before therapy	4.21±1.03	4.18±1.06	0.157	0.876
	2 months after therapy	2.01±0.46	2.88±0.52	-9.707	<0.001

FINS, fasting insulin; HOMA-IR, Homeostatic Model Assessment of Insulin Resistance.

Comparison of Blood Lipid Levels

Before treatment, there was no statistically significant difference in the levels of triacylglycerol, total cholesterol, HDL-C, and LDL-C between the two groups (p>0.05), while the four levels in the study group were significantly lower than those in the control group two months after treatment (p<0.05), as summarized in Table III.

Comparison of Quality of Life

There were no statistically significant differences in scores of physiological, psychological, social, and therapy-related problems between the two groups before treatment (p>0.05), whereas the abovementioned scores were evidently higher in the study group than in the control group two months after treatment (p<0.05), as shown in Table IV.

Discussion

Diabetes mellitus is a chronic condition that arises from multiple etiologies. Its primary clinical features include cachexia, polyuria, polydipsia, and other associated symptoms[12]. Inadequate regulation of blood glucose levels may lead to various complications. Statistics indicate that obesity accounts for more than 60% of diabetic patients in China. Compared with the increase in adipose tissue in the drooping part of the body, it has a greater impact on the metabolic level and affects insulin resistance, consequently inducing endocrine disorders, respiratory diseases, and cardiovascular and cerebrovascular diseases[13]. Therefore, both domestic and international guidelines pertaining to diabetes underscore the importance of being aware and regulating the body

Table III. Comparison of blood lipid levels ($\bar{\chi}$±s).

Parameter	Time	Study group (n=60)	Control group (n=60)	*t*	*p*
Triacylglycerol (mmol/L)	Before therapy	2.11±0.38	2.07±0.43	0.541	0.589
	2 months after therapy	1.76±0.34	1.92±0.32	-2.654	0.002
Total cholesterol (mmol/L)	Before therapy	5.67±1.27	5.61±1.32	0.254	0.799
	2 months after therapy	4.02±1.08	4.63±1.18	-2.954	0.004
HDL-C (mmol/L)	Before therapy	1.29±0.22	1.27±0.24	0.476	0.635
	2 months after therapy	1.43±0.21	1.32±0.23	2.736	0.007
LDL-C (mmol/L)	Before therapy	3.33±0.32	3.41±0.39	-1.228	0.222
	2 months after therapy	2.45±0.45	2.78±0.43	-4.107	<0.001

HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein.

Table IV. Comparison of quality of life ($\bar{\chi}$±s).

Parameter	Time	Study group (n=60)	Control group (n=60)	*t*	*p*
Social relation	Before therapy	10.65±2.18	10.72±2.32	-0.170	0.865
	2 months after therapy	17.92±2.31	14.17±2.43	8.664	<0.001
Psychological health	Before therapy	15.02±2.71	15.08±2.83	-0.119	0.905
	2 months after therapy	20.87±2.87	17.28±2.37	7.471	<0.001
Physiological function	Before therapy	36.18±2.76	36.65±3.02	-0.891	0.375
	2 months after therapy	50.29±3.27	42.19±3.47	13.159	<0.001
Therapy-related problem	Before therapy	3.26±1.01	3.23±1.07	0.158	0.875
	2 months after therapy	4.76±1.23	4.01±1.27	3.286	0.001

weight of individuals suffering from diabetes[14,15]. The effective management of overweight patients with early-onset type 2 diabetes poses a critical clinical challenge.

Due to the relatively insufficient absorption of nutrients in early type 2 diabetes patients, the nutrition of the body is largely affected, thus reducing the immune function. As a result, the condition increases the incidence of related complications, leading to poor prognosis and a reduced quality of life for patients[16]. Therefore, the nutritional status of early type 2 diabetes patients is deemed as the focus of clinical attention. A low-calorie diet intervention aims to correct glucose and lipid metabolism disorders while meeting the body's nutritional needs, thereby preventing the occurrence of complications. For obese patients with type 2 diabetes, calorie control is particularly critical to prevent further deterioration of the disease[17]. Zubrzycki et al[17] confirmed that a low-calorie diet intervention could significantly reduce BMI and metabolic level of obese patients with type 2 diabetes. Similarly, Moriconi et al[18] suggested that a low-calorie diet intervention could effectively reduce BMI and HbAIc levels of obese patients with type 2 diabetes. Moreover, aerobic training is able to accelerate the heart rate and rapidly consume energy, which markedly enhances the aerobic exercise ability and physical fitness level, with a beneficial effect on the glucose metabolism disorder caused by type 2 diabetes[19]. According to Magalhães et al[19], aerobic exercise could reduce HbA1c and other indicators in patients with type 2 diabetes. In our study, two months after treatment, the FBG, 2hPG, and HbAIc levels were greatly lower, and the levels of ALB, PA, and Hb were significantly higher in the study group than those in the control group ($p<0.05$). It was suggested that a low-calorie diet intervention combined with aerobic training could greatly regulate the levels of FBG, 2hPG, HbAIc, ALB, PA and Hb in obese patients with early type 2 diabetes mellitus, as well as regulate the nutritional status. The possible reason for this result could be attributed to the synergistic effect of low-calorie diet intervention and aerobic training, which was built upon a tailored and healthy diet plan and aerobic training program specifically designed for obese individuals with early-onset type 2 diabetes mellitus. Through timely and targeted counseling and recommendations, patients were able to gradually regulate their daily diet and exercise routines, leading to constant adjustments to the intervention plan and significant improvement in their nutritional status. Furthermore, aerobic exercise has been found to modulate glucose metabolism by augmenting insulin secretion and enhancing insulin sensitivity in surrounding tissues, thereby achieving the ultimate goal of reducing blood glucose levels.

According to a recent study[20], a low-calorie diet could significantly reduce the blood sugar and visceral fat content of early overweight or obese type 2 diabetes patients and improve the function of pancreatic islets. Another study[21] also showed that a low-calorie diet could reduce the levels of FBG, PBG and HbAIc levels in obese patients with type 2 diabetes, with improved body mass and blood glucose indicators, and better recovery. An earlier study[22] depicted that aerobic exercise exerted a good effect in promoting the liver release and muscle uptake of glucose, alongside an increased number of insulin receptors on the cell membrane and sensitivity of body tissues to insulin action in the liver, skeletal muscle cells, adipose tissue, etc. In their study, aerobic exercise could also enhance the affinity of insulin to its receptors and reduce the total body fat content, thereby achieving the goal of improving insulin resistance. The results of this study demonstrated that two months after treatment, the levels of FINS and HOMA-IR values in the study group were evidently lower than those in the control group ($p<0.05$), suggesting that a low-calorie diet intervention combined with aerobic training effectively reduced the levels of FINS and HOMA-IR in obese patients with early type 2 diabetes. These results may be due to the fact that a low-calorie diet intervention combined with aerobic training can help the body consume the free fatty acids formed by the decomposition of triacylglycerol in adipose tissue and the glucose released by the liver. By reducing the impact of lipid and glucose toxicity on pancreatic function, it can reduce the burden on the pancreas while allowing the islet cells to rest fully, and restore some of the islet function, subsequently improving pancreatic resistance.

In patients with early type 2 diabetes, the removal of endogenous and exogenous triglycerides is weakened due to insufficient insulin; hence, the levels of blood triacylglycerol and total cholesterol may change abnormally[23]. Abnormal lipid metabolism is an independent risk factor for diabetes, and with the progression of the disease, the degree of lipid disorder becomes more significant. At present, the reduction of body mass, blood sugar, blood pressure and blood lipids is regarded as the main target and consensus for the management of overweight or obese diabetes patients[23]. MacPherson et al[24] showed that diet and exercise intervention could greatly regulate the blood lipid level and reduce the blood sugar level among type 2 diabetes patients. Similarly, Zhang and Zhu[25] suggested that aerobic exercise could regulate blood sugar and blood lipid levels in patients with prediabetes. In our study, levels of triacylglycerol, total cholesterol, HDL-C and LDL-C in the study group were lower than those in the control group 2 months after treatment ($p<0.05$), indicating that a low-calorie diet intervention combined with aerobic training was able to effectively regulate the levels of the abovementioned levels in obese patients with early type 2 diabetes, and exert the role of regulating the level of blood lipids. This may be linked to the combined effect of low-calorie diets and aerobic training intervention, which complement anaerobic metabolism and aerobic metabolism, further improving glucose intake and utilization rate, thereby regulating blood lipid levels.

The assessment of the quality of life can furnish healthcare professionals with a holistic understanding of patients' physical, mental, and social adjustment, enabling a quantitative evaluation of the disease's impact on their health. Moreover, it facilitates the identification of potential influencing factors and the implementation of targeted intervention measures[26]. Currently, the DSQL scale is widely applied to evaluate the quality of life of patients with type 2 diabetes. An effective diet intervention could improve the level of glucose metabolism in elderly patients with type 2 diabetes, thereby improving the quality of life of patients[26]. Dietary intervention exhibited obvious effects in patients with type 2 diabetes, which optimized their dietary patterns, effectively controlled blood sugar levels and improved their quality of life[27]. Toi et al[28] believe that dietary intervention can control the blood lipid level of patients with type 2 diabetes and improve their quality of life. Research by Jamshidpour et al[29] pointed out that exercise training could improve the quality of life of hemodialysis patients with type 2 diabetes mellitus. According to Molsted and Jensen[30], exercise training significantly controlled the blood sugar level of patients with type 2 diabetes, thus improving the quality of life of patients. In our study, two months after treatment, the scores of social relations, psychological and mental health, physiological function and treatment-related problems of the study group were higher than those of the control group ($p<0.05$), suggesting that a low-calorie diet intervention combined with aerobic training could markedly improve the quality of life of obese patients with early type 2 diabetes mellitus. The possible reason for this result could be attributed to the synergistic effect of low-calorie diet intervention and aerobic training, which is able to effectively control blood sugar levels, and improve the patients' social and psychological status, thereby improving their quality of life.

Conclusions

A low-calorie diet intervention combined with aerobic training exerted good effects in terms of greatly enhancing the nutritional status, reducing FINS and HOMA-IR values, and regulating blood lipid levels, with increased quality of life among obese patients with early type 2 diabetes mellitus, which was deemed appropriate for clinical promotion and implementation. However, there were limitations in the present study. Considering the restricted areas and sample size included in our study, multi-center studies of obese patients with early type 2 diabetes are warranted to confirm the current findings.

Ethics Approval

Informed consent was obtained from all participants.

Ethics Approval

The study was approved by the Ethics Committee of Liaoning Cancer Hospital (No. LNEIC-0110).

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Conflict of Interest

The authors declare there is no conflict of interest.

Authors' Contributions

H.W. contributed to the conception and design of the study. All authors participated in the clinical practice, including diagnosis, treatment, consultation and follow-up of patients. D.A. contributed to the acquisition of data. N.D. contributed to the analysis of data. H.W. wrote the manuscript. D.A. and J.W. revised the manuscript. All authors approved the final version of the manuscript.

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Availability of Data and Materials

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

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