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Efficacy of a Low-Carbohydrate Diet in the Treatment of Type 2 Diabetes

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Abstract. This study aimed to evaluate the efficacy, sustainability and long-term safety of a low-carbohydrate diet (LCD) in the treatment of type 2 diabetes. A randomized controlled trial was conducted involving 178 patients, who were randomly assigned to receive either a standard diet or a 30% carbohydrate LCD for 6 months. A total of 163 patients completed the trial. Compared with the standard diet group, the LCD group showed significantly better improvements in fasting blood glucose, 2-hour postprandial blood glucose, glycosylated hemoglobin, blood lipid profile and HOMA-IR. The results indicate that a 30% low-carbohydrate diet effectively improves glycemic and lipid control in patients with type 2 diabetes. However, long-term adherence is challenging, and nutritional balance should be guaranteed. Medication adjustment may be needed in clinical practice. This dietary intervention is not suitable for all patients and should be applied based on individual conditions.

Keywords: type 2 diabetes, low - carbohydrate diet, blood sugar, dietary intervention, type 2 diabetes management

1. Introduction

A common metabolic disorder, type 2 diabetes, is experiencing an increase in its global prevalence. It accounts for over 90% of all diabetes diagnoses [1]. If not properly managed, it can cause serious damage to many organ systems. Complications such as cardiovascular and neurological diseases may arise. Many clinical studies have shown that a LCD can effectively lower glycated hemoglobin (HbA1c) levels [2]. For instance, one study indicated that for some patients with severe type 2 diabetes (HbA1c ≥ 9.0%), a diet where carbohydrates constitute 30% of their energy intake can help maintain good blood sugar control [3]. Reducing carbohydrate intake can improve blood sugar control [4].

The American Diabetes Association (ADA) has rules. These rules clearly say one thing is okay. Eating fewer total carbs helps people with type 2 diabetes [5]. It improves their hyperglycemia. Many studies have discovered something else. A low-carbohydrate diet is effective. It assists these patients in maintaining blood sugar control. It also aids them in managing their weight. It also impacts their cardiovascular metabolic indicators. There aren't many randomized controlled trials available. These trials concentrate on the benefits of a low-carb diet for diabetics. This study created two groups for comparison. One group followed the Dietary Guidelines for Chinese Residents. We

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refer to this group as the standard diet group. The other group consumed a 30% low-carbohydrate diet. We refer to this group as the experimental group. Researchers have a definition for a LCD. It's a type of eating plan. Carbohydrates in it account for a portion of the daily energy intake. It helps the body achieve a healthier metabolism. It aids in proper weight management. It also corrects blood sugar levels. Many patients struggled. They were unable to maintain a low-carb diet for extended periods [6]. Implementing this diet in real-world situations requires careful attention. Nutritional balance is crucial. It is the key to making this diet successful [7]. This diet is not suitable for all individuals with type 2 diabetes. Certain factors need consideration. Health status, complications, and cultural background are personal aspects [8]. This randomized controlled trial has an objective. It aims to investigate the precise effect. The effect stems from the 30% low-carb diet's assistance for type 2 diabetes.

2. Materials and methods

2.1. Research object

In Nanjing, individuals were recruited for this study. The research had specific inclusion criteria. A key criterion was a diagnosis of type 2 diabetes, which adhered to the World Health Organization (WHO) guidelines. Another criterion is no major dietary changes. Participants didn’t make such changes three months before the trial. They also didn’t take part in other dietary intervention studies during that time. There are exclusion criteria as well. Liver or kidney dysfunction is one. Acute cardiovascular disease is another. Pregnancy or lactation is also an exclusion. Some diseases affect dietary intake. These diseases are exclusion criteria too. Things like oral diseases or a history of gastrointestinal surgery are examples. People who can’t follow the dietary intervention are excluded. Those who can’t attend regular follow-up are also excluded.

2.2. Research and design

A randomized controlled trial was conducted. Type 2 diabetes patients meeting the criteria were randomly assigned to two cohorts: one adhered to the Dietary Guidelines for Chinese Residents (the standard diet cohort), while the other underwent a low-carbohydrate diet (LCD) regimen. The objective was to assess how these two dietary approaches influenced diverse health metrics. All participants provided written informed consent. Public baseline data collection

All participants provided basic information, such as their age, sex, mass, body mass index, diabetes course and family history.

The follow - up data is collected monthly by the 24- hour meal recall method. The research follow up is scheduled on the baseline, the 4th and 8th weeks of the intervention, and 6 months after the follow - up. In each follow - up visit, measure the height and weight of the participants and collect blood samples. Utilize conventional clinical laboratory protocols to assess glycated hemoglobin (HbA1c), fasting plasma glucose (FPG), 2-hour post-meal blood glucose (2h-PPG), blood triglyceride levels, insulin resistance index (HOMA-IR), and total cholesterol.

2.2.1. Standard diet group

The group follows the recommendations of the " Resident Dietary Guidelines ": eat more than 12kinds of food per day and more than 25 kinds of food per week ; salt intake is limited to ≤6g/ day , cooking oil 25-30g/ day, added sugar ≤50g/ day; Consume animal products like fish, poultry, eggs,

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and lean meats in moderation. Daily vegetable intake should be 300-500 grams, with dark vegetables comprising half of this amount, fruit intake is 200-350 grams, and milk and dairy products intake is 300grams; drink 7-8 cups of water every day.

2.2.2. Low - carbohydrate diet (LCD) group

Individuals within this cohort were instructed to decrease their consumption of foods rich in carbohydrates (like pasta, rice, and bread), increase the intake of foods rich in protein and healthy fats (such as fish, seafood, meat, soy products, olive oil, nuts), with carbohydrate intake accounting for 30% of daily energy intake. In order to ensure that they can adapt well to a low - carbohydrate diet, professional nutritionists will regularly communicate with participants and introduce various diet patterns that help control blood sugar and support weight loss[9]. The diet intervention plan will be adjusted according to the feedback and actual situation of the participants.

3. Result

3.1. Characteristics of participants

Initially, a total of 187 participants joined the group. According to the inclusion criteria ,178 participants were eligible for the study. The reasons for exclusion include :3 patients refused to participate because they were older (>89 years old), and 6 were excluded because of incomplete follow - up data. Throughout the investigation, 15 individuals departed (6 from the standard diet cohort and 9 from the low-carbohydrate diet cohort). Of these, 10 (6 from the standard diet group and 4 from the low-carbohydrate diet group) were not accounted for in subsequent follow-ups. The remaining 5 participants from the low-carbohydrate diet group were omitted due to non-adherence to dietary guidelines. Ultimately, 163 participants concluded this study (83 in the standard diet group, 80 in the low-carbohydrate diet group). The age spectrum for participants spanned 22 to 71 years, and the average age is 45.61± 12.30 years old. The course of diabetes ranges from 0.11 to 19.46 years, with an average of 9.80-4.92 years.

3.2. Comparison of baseline data

Table 1. Pre-intervention data comparison between two cohorts of type 2 diabetes patients

Variable	Standard group	Low-carbohydrate diet group	P=
Glycosylated hemoglobin（%）	9.73±2.11	9.66±1.84	0.821
Fasting blood glucose（mmol/L）	9.09±3.44	9.03±2.51	0.899
Postprandial 2-hour blood glucose（mmol/L）	12.89±4.82	12.94±3.89	0.942
Blood triglycerides（mmol/L）	3.99±0.91	4.03±1.00	0.790
Total cholesterol（mmol/L）	6.18±1.84	6.21±2.94	0.938
HOMA-IR	4.50±2.33	3.98±1.83	0.116

The data (Table 1) revealed no statistically significant variations between the group consuming a standard diet and the group on a low-carbohydrate diet concerning glycated hemoglobin (9.73% ± 2.11% vs. 9.66% ± 1.84%, P=0.821), fasting plasma glucose (9.09 ± 3.44 mmol/L vs. 9.03 ± 2.51 mmol/L, P=0.899), 2-hour post-meal blood glucose (12.89 ± 4.82 mmol/L vs. 12.94 ± 3.89 mmol/L, P=0.942), triglycerides (3.99 ± 0.91 mmol/L vs. 4.03 ± 1.00 mmol/L, P=0.790), total cholesterol

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(6.18 ± 1.84 mmol/L vs. 6.21 ± 2.94 mmol/L, P=0.938), or HOMA-IR (4.50 ± 2.33 vs. 3.98 ± 1.83, P=0.116). These findings suggest that the two cohorts were comparable at the outset.

3.3. Blood sugar related indicators

Table 2. Comparison of data in the two groups of patients with type 2 diabetes after 6-months intervention

Variable	Standard group	Low-carbohydrate diet group	P=
Glycosylated hemoglobin（%）	6.83±2.11	4.58±0.85	<0.001
Fasting blood glucose（mmol/L）	6.88±3.82	4.91±1.73	<0.001
Postprandial 2-hour blood glucose（mmol/L）	8.23±2.84	5.61±2.06	<0.001
Blood triglycerides（mmol/L）	3.06±0.61	2.41±0.44	<0.001
Total cholesterol（mmol/L）	5.33±1.61	5.19±2.05	0.628
HOMA-IR	3.00±1.26	2.31±0.95	<0.001

After six months of dietary intervention, many metabolic indicators of both groups improved, among which the low - carbohydrate diet (LCD) group improved more significantly (Table 2).

3.4. Blood glucose-related indicators

3.4.1. Glycated hemoglobin

The standard diet group's glycated hemoglobin ended up at 6.83% ± 2.11%.The LCD group's glycated hemoglobin ended up at 4.58% ± 0.85%.These two groups had a real difference in statistics (P<0.001).Glycated hemoglobin for the standard diet group at first was 9.73% ± 2.11%.It dropped down to 6.83% ± 2.11%.Glycated hemoglobin for the LCD group at first was 9.66% ± 1.84%.It dropped down to 4.58% ± 0.85% (P<0.001).

3.4.2. Fasting blood glucose (FBG)

Fasting blood glucose for the standard diet group at first was 9.09 ± 3.44 mmol/L. It dropped down to 6.88 ± 3.82 mmol/L. Fasting blood glucose for the LCD group at first was 9.03 ± 2.51 mmol/L. It dropped down to 4.91 ± 1.73 mmol/L (P<0.001).

3.4.3. Two-hour postprandial blood glucose (2h-PPG)

Two-hour postprandial blood glucose for the standard diet group at first was 12.89 ± 4.82 mmol/L. It dropped down to 8.23 ± 2.84 mmol/L. Two-hour postprandial blood glucose for the low-carbohydrate diet group at first was 12.94 ± 3.89 mmol/L. It dropped down to 5.61 ± 2.06 mmol/L (P<0.001). The cohort on a low-carbohydrate eating plan demonstrated superior blood sugar management.

3.5. Lipid indicators

Triglycerides for the standard diet group at first were 3.99 ± 0.91 mmol/L. They dropped down to 3.06 ± 0.61 mmol/L. Initially, the low-carbohydrate diet group's triglyceride levels were measured at

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4.03 ± 1.00 mmol/L. They dropped down to 2.41 ± 0.44 mmol/L. These two groups had a plain difference (P<0.001). Total cholesterol went down just a bit in both groups. Total cholesterol for the standard diet group at first was 6.18 ± 1.84 mmol/L. It turned into 5.33 ± 1.61 mmol/L. The initial total cholesterol level for the low-carbohydrate diet group was 6.21 ± 2.94 mmol/L, which subsequently shifted to 5.19 ± 2.05 mmol/L. The difference between groups wasn't real when looking at stats (P=0.628).

3.6. Insulin resistance

HOMA-IR for the standard diet group at first was 4.50 ± 2.33. It dropped down to 3.00 ± 1.26. Initially, the HOMAIR for individuals on the low-carbohydrate diet (LCD) measured 3.98 ± 1.83. This value subsequently decreased to 2.31 ± 0.95. The difference between groups was plain (P<0.001). The group following a low-carbohydrate diet showed a more pronounced improvement in insulin resistance.

3.7. Summary

For individuals with type 2 diabetes, a dietary regimen low in carbohydrates has exhibited considerable promise in enhancing blood glucose regulation, facilitating reductions in body weight, and ameliorating certain metabolic markers related to cardiovascular health [7].

4. Discussion

In individuals with type 2 diabetes, a low-carbohydrate diet (LCD) intervention leads to more pronounced metabolic enhancements compared to a standard diet. This dietary approach is more effective in lowering glycated hemoglobin, fasting and postprandial blood glucose concentrations, alleviating insulin resistance, and decreasing triglyceride levels. Nevertheless, no substantial difference in total cholesterol management was observed between the two groups. Furthermore, the comparable baseline characteristics of the initial two intervention groups lent additional support to the favorable regulatory impact of a low-carbohydrate diet on metabolic markers in type 2 diabetic patients.

5. The impact of a low-carb dietary regimen (LCD) on type 2 diabetes treatment.

5.1. Blood sugar control got way better all over.

A 30% low-carb diet brought glycated hemoglobin down a good bit. It went from 9.66% ± 1.84% to 4.58% ± 0.85%. Fasting blood glucose (FBG) went down too. It dropped from 9.03 ± 2.51 mmol/L to 4.91 ± 1.73 mmol/L. Similarly, 2h-PPG also demonstrated this trend. It fell from 12.94 ± 3.89 mmol/L to 5.61 ± 2.06 mmol/L. All three indicators ended up doing better. These changes were notably superior to those observed in the conventional diet group (P<0.001).

5.2. Insulin resistance decreased significantly

Within the 30% low-carbohydrate diet cohort, HOMA-IR demonstrated a more pronounced enhancement, decreasing from 3.98±1.83 to 2.31±0.95. This was in contrast to the standard diet group, which saw a change from 4.50±2.33 to 3.00±1.26 (P<0.001). This shows that the diet can enhance insulin sensitivity and reduce the need for insulin in these patients.

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5.3. Effective decrease in triglyceride levels

A 30% low-carb diet brought triglyceride levels down. They went from 4.03 ± 1.00 mmol/L to 2.41 ± 0.44 mmol/L. This drop was way bigger than the standard diet group' s. That group's levels went from 3.99 ± 0.91 mmol/L to 3.06 ± 0.61 mmol/L ($P<0.001$). This shows the diet fixed lipid metabolism problems in these patients.

5.4. No additional effect on total cholesterol

While total cholesterol modestly declined in the group consuming a 30% low-carbohydrate diet, from 6.21±2.94-mmol/L to 5.19±2.05mmol/L, compared with the standard diet group (from 6.18±1.84mmol/L to 5.33±1.61mmol/L) is not significant in comparison.

The difference ($P=0.628$) shows that the effect of this diet on total cholesterol is similar to that of the traditional standard diet.

6. Conclusion

After six months of intervention, the improvement in glycated hemoglobin, fasting blood glucose ,2-hour postprandial blood sugar, triglyceride and insulin resistance index in the low - carbohydrate diet (LCD) intervention group was significantly better than that of the standard diet group. This study shows that a 30% low - carbohydrate diet intervention can significantly help patients with type 2 diabetes to reduce blood sugar and blood lipid levels, and have a beneficial impact on other health indicators [10]. It may also prevent adverse reactions such as hypoglycemia and support patient recovery.

However, this diet pattern is difficult to maintain for a long time, there is a risk of malnutrition, and medication may need to be adjusted. Therefore, dietary intervention should be carried out under the close supervision of medical professionals [11]. Future research should continue to explore the long - term safety and effectiveness of low - carbohydrate diets in different populations and determine the best way to implement this diet pattern in clinical practice [1].

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Disclosure of competing interests

The authors state that there are no competing interests.

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