

## Effect of A Modified Ketogenic Diet on Carbohydrate and Lipid Metabolism in Experimental Metabolic Syndrome

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### Abstract

*Metabolic syndrome is a complex metabolic condition characterized by insulin resistance, hyperglycemia, and atherogenic dyslipidemia, and modification of dietary composition is considered an important approach to its correction. The aim of the study was to dynamically and comparatively evaluate the effect of a modified ketogenic diet on carbohydrate and lipid metabolism parameters under conditions of experimental metabolic syndrome. During the correction stage, the animals were divided into seven groups: intact control, metabolic syndrome control, MS + traditional ketogenic diet (TKD), MS + modified ketogenic diet (MKD), MS + ezetimibe, MS + metformin, and MS + metformin + ezetimibe (n=8 in each group). The MKD consisted of 60% fat, 30% protein, and 10% carbohydrate. Correction was continued for 30 days, and glucose, insulin, total cholesterol, triglycerides (TG), low-density lipoproteins (LDL), and high-density lipoproteins (HDL) were assessed on days 10, 20, and 30. In the MKD group, glucose decreased from 6.9 mmol/L on day 10 to 4.8 mmol/L on day 30, insulin from 20.6 to 17.7, total cholesterol from 5.8 to 3.3 mmol/L, TG from 1.70 to 1.22 mmol/L, and LDL from 0.93 to 0.59 mmol/L, whereas HDL increased from 0.61 to 0.70 mmol/L. The results demonstrated that MKD was associated with favorable correction of carbohydrate and lipid metabolism disturbances in experimental metabolic syndrome.*

**Keywords:** Metabolic syndrome, modified ketogenic diet, glucose, insulin, lipid metabolism, cholesterol, triglycerides, LDL, HDL.

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### 1. Introduction

Metabolic syndrome is a cluster of interrelated metabolic disorders, including abdominal obesity, insulin resistance, hyperglycemia, arterial hypertension, and atherogenic

dyslipidemia, and is associated with an increased risk of type 2 diabetes mellitus and cardiovascular disease [1–3]. In its pathogenesis, impaired insulin action plays an important role by reducing glucose utilization in peripheral tissues, increasing hepatic glucose production, and activating

lipolysis in adipose tissue. Excessive influx of free fatty acids into the liver promotes triglyceride synthesis and alterations in lipoprotein metabolism, thereby contributing to the development of an atherogenic lipid profile [2,3]. Therefore, correction of metabolic syndrome requires targeting lipid metabolism disturbances in addition to achieving glycemic control.

In recent years, interest in carbohydrate-restricted and ketogenic dietary models for the correction of metabolic disorders has increased. Meta-analyses indicate that low-carbohydrate diets may have favorable effects on glycemic control, triglycerides, and HDL in metabolic syndrome and type 2 diabetes mellitus [4–7]. However, the effect of ketogenic diets on the lipid profile, particularly LDL and total cholesterol, is inconsistent; some pooled analyses have reported increases in these parameters [5,8,9]. This suggests that the metabolic response may depend on the macronutrient composition and duration of the diet as well as the baseline metabolic status. From this perspective, dynamic investigation of the effects of an MKD containing 60% fat, 30% protein, and 10% carbohydrate on carbohydrate and lipid metabolism in experimental metabolic syndrome is of scientific interest.

The aim of the study was to dynamically evaluate the effects of a modified ketogenic diet on glucose, insulin, total cholesterol, triglycerides, LDL, and HDL on days 10, 20, and 30 under conditions of experimental metabolic syndrome and to comparatively analyze its metabolic efficacy with a traditional ketogenic diet and pharmacological correction groups.

## 2. Methods

The study was conducted in adult Chinchilla rabbits with an initial body weight of 2.2–2.4 kg. Experimental metabolic syndrome was modeled for 60 days according to the method of Saidov S.A. (2006): the animals received crystalline

cholesterol at a dose of 250 mg/kg daily, a 5% sucrose solution was provided instead of drinking water, and insulin was administered subcutaneously at a dose of 0.1 U/100 g every other day. During the correction stage, the animals were divided into seven groups, with eight animals in each group: I — intact control; II — MS control; III — MS + TKD; IV — MS + MKD; V — MS + ezetimibe; VI — MS + metformin; VII — MS + metformin + ezetimibe. Ezetimibe was administered at 0.14 mg/kg/day and metformin at 25 mg/kg/day; the correction period lasted 30 days.

The macronutrient ratio of the TKD was 70% fat, 20% protein, and 10% carbohydrate, whereas the MKD consisted of 60% fat, 30% protein, and 10% carbohydrate; egg white was used as the protein source in the MKD. Assessments were performed on days 10, 20, and 30 of correction. Carbohydrate metabolism was evaluated using glucose and insulin levels, while lipid metabolism was assessed using total cholesterol, TG, LDL, and HDL. Statistical analysis was performed using SPSS 26.0; data distribution was assessed with the Shapiro–Wilk test, intergroup differences were evaluated using Student's t-test and ANOVA, and multiple comparisons were performed using Tukey's post-hoc test. A value of  $p < 0.05$  was considered statistically significant.

## 3. Results

Modeling experimental metabolic syndrome for 60 days resulted in pronounced disturbances of carbohydrate and lipid metabolism. Glucose increased from  $3.4 \pm 0.32$  mmol/L to  $14.6 \pm 1.3$  mmol/L, insulin from  $16.7 \pm 1.64$  to  $26.9 \pm 2.5$ , total cholesterol from  $2.7 \pm 0.26$  to  $7.6 \pm 0.73$  mmol/L, TG from  $1.2 \pm 0.11$  to  $2.3 \pm 0.20$  mmol/L, and LDL from  $0.53 \pm 0.05$  to  $1.15 \pm 0.11$  mmol/L, whereas HDL decreased from  $0.76 \pm 0.07$  to  $0.47 \pm 0.04$  mmol/L. Thus, by day 60, an atherogenic lipid profile had developed together with hyperglycemia and hyperinsulinemia.

**Table 1. Dynamics of glucose and insulin parameters during the correction period**

| Group          | Glucose 10 | 20   | 30   | Insulin 10 | 20   | 30   |
|----------------|------------|------|------|------------|------|------|
| Intact control | 3,4        | 3,4  | 3,4  | 16,7       | 16,7 | 16,7 |
| MS control     | 13,5       | 14,6 | 15,0 | 25,1       | 26,9 | 28,2 |
| MS + TKD       | 11,5       | 9,5  | 8,2  | 23,0       | 19,9 | 19,0 |
| MS + MKD       | 6,9        | 6,8  | 4,8  | 20,6       | 18,9 | 17,7 |
| MS + Ezetimibe | 12,5       | 9,1  | 8,8  | 23,4       | 20,4 | 20,1 |
| MS + Metformin | 9,4        | 9,0  | 8,8  | 23,9       | 19,7 | 19,7 |

|                             |     |     |     |      |      |      |
|-----------------------------|-----|-----|-----|------|------|------|
| MS +<br>Metformin+Ezetimibe | 6,6 | 6,2 | 4,5 | 21,2 | 17,9 | 17,7 |
|-----------------------------|-----|-----|-----|------|------|------|

In the MS control group, glucose continued to increase from 13.5 mmol/L on day 10 to 15.0 mmol/L on day 30, whereas in the MKD group it decreased from 6.9 to 4.8 mmol/L, representing a 30.4% reduction. On day 30, glucose was 8.2 mmol/L in the TKD group, 8.8 mmol/L in both the ezetimibe and metformin groups, and 4.5 mmol/L in the

metformin + ezetimibe group. Insulin also increased from 25.1 to 28.2 in the MS control group, whereas it decreased from 20.6 to 17.7 in the MKD group. This pattern demonstrated a consistent favorable change in carbohydrate metabolism parameters during MKD correction.

**Table 2. Dynamics of lipid metabolism parameters during the correction period, mmol/L**

| Group        | TC<br>10 | 20  | 30  | TG 10 | 20   | 30   | LDL 10 | 20   | 30   | HDL 10 | 20   | 30   |
|--------------|----------|-----|-----|-------|------|------|--------|------|------|--------|------|------|
| Intact       | 2,7      | 2,7 | 2,7 | 1,20  | 1,20 | 1,20 | 0,53   | 0,53 | 0,53 | 0,76   | 0,76 | 0,76 |
| MS           | 7,3      | 7,6 | 8,0 | 2,20  | 2,30 | 2,40 | 1,20   | 1,15 | 1,25 | 0,53   | 0,47 | 0,49 |
| MS+TKD       | 6,5      | 5,7 | 5,4 | 2,00  | 1,60 | 1,45 | 1,10   | 0,93 | 0,90 | 0,58   | 0,62 | 0,63 |
| MS+MKD       | 5,8      | 4,0 | 3,3 | 1,70  | 1,30 | 1,22 | 0,93   | 0,88 | 0,59 | 0,61   | 0,65 | 0,70 |
| MS+Ezet      | 6,9      | 5,2 | 5,1 | 2,10  | 1,80 | 1,60 | 1,13   | 1,09 | 0,99 | 0,56   | 0,58 | 0,59 |
| MS+Metf      | 7,0      | 5,1 | 4,8 | 1,90  | 1,60 | 1,40 | 1,11   | 0,98 | 0,85 | 0,52   | 0,63 | 0,67 |
| MS+Metf+Ezet | 4,9      | 2,9 | 2,5 | 1,80  | 1,35 | 1,23 | 0,96   | 0,70 | 0,57 | 0,63   | 0,68 | 0,71 |

The favorable dynamics of carbohydrate metabolism were accompanied by changes in the lipid profile in the same direction. By day 30, total cholesterol in the MS control group was 8.0 mmol/L, TG 2.40 mmol/L, and LDL 1.25 mmol/L, while HDL remained at 0.49 mmol/L. In the MKD group, total cholesterol decreased from 5.8 to 3.3 mmol/L (43.1%), TG from 1.70 to 1.22 mmol/L (28.2%), and LDL from 0.93 to 0.59 mmol/L (36.6%), whereas HDL increased from 0.61 to 0.70 mmol/L (14.8%). On day 30, total cholesterol, TG, LDL, and HDL in the TKD group were 5.4, 1.45, 0.90, and 0.63 mmol/L, respectively, compared with 3.3, 1.22, 0.59, and 0.70 mmol/L in the MKD group. Marked correction of the lipid profile was observed in the metformin + ezetimibe group, where total cholesterol was 2.5 mmol/L, TG 1.23 mmol/L, LDL 0.57 mmol/L, and HDL 0.71 mmol/L. Although some final values in the MKD group approached those of the combined pharmacological group, this finding is insufficient to interpret the diet as equivalent or superior to pharmacotherapy.

#### 4. Discussion

The obtained results demonstrated that disturbances of carbohydrate and lipid metabolism develop in an interrelated manner under conditions of experimental metabolic syndrome. In the MS control group, progressive increases in glucose and insulin were accompanied by high levels of total cholesterol, TG, and LDL and by reduced

HDL. In contrast, MKD produced an opposite pattern: by day 30, the reduction in glucose to 4.8 mmol/L was accompanied by a decrease in insulin to 17.7, while total cholesterol, TG, and LDL decreased to 3.3, 1.22, and 0.59 mmol/L, respectively, together with an increase in HDL to 0.70 mmol/L. This direction is generally consistent with a 2025 meta-analysis showing that low-carbohydrate diets may reduce HbA1c and TG and increase HDL in metabolic syndrome [4], as well as with an analysis reporting reduction in glucose and TG and an increase in HDL in type 2 diabetes associated with overweight or obesity [7].

However, the effects of ketogenic diets on lipid metabolism are not uniform. A 2023 umbrella review reported high-quality evidence for a reduction in TG with ketogenic diets while also indicating that a clinically meaningful increase in LDL may occur [5]. A 2026 meta-regression including 53 randomized controlled trials likewise found reductions in TG and increases in HDL together with average increases in LDL and total cholesterol [8]; a separate 2026 analysis reported a similar direction [9]. In our model, however, both LDL and total cholesterol decreased during MKD. This discrepancy may be related to the characteristics of the experimental model, the 60:30:10 macronutrient ratio, the 30-day observation period, and the baseline metabolic status. Therefore, these findings should not be interpreted as evidence of a universal LDL-lowering effect of all ketogenic diets. The more pronounced favorable dynamics

of several parameters with MKD compared with TKD suggest that not only carbohydrate restriction but also macronutrient composition may contribute to the metabolic response; confirmation of this hypothesis at a mechanistic level requires separate investigation of ketone bodies, fatty acid composition, and molecular signaling pathways.

## 5. Conclusion

Administration of a modified ketogenic diet for 30 days in experimental metabolic syndrome was associated with consistent favorable dynamics in carbohydrate and lipid metabolism parameters. In the MKD group, reductions in glucose and insulin occurred simultaneously with decreases in total cholesterol, TG, and LDL and an increase in HDL; on day 30, glucose was 4.8 mmol/L, total cholesterol 3.3 mmol/L, TG 1.22 mmol/L, LDL 0.59 mmol/L, and HDL 0.70 mmol/L. MKD showed more pronounced favorable dynamics than TKD for several parameters, while some final values approached those observed in the metformin + ezetimibe group. The results indicate the potential of an MKD containing 60% fat, 30% protein, and 10% carbohydrate to correct disturbances of carbohydrate and lipid metabolism in experimental metabolic syndrome; however, its long-term safety and clinical efficacy should be evaluated in separate studies.

## References

1. Alberti K.G.M.M., Eckel R.H., Grundy S.M., et al. Harmonizing the metabolic syndrome: a joint interim statement. *Circulation*. 2009;120(16):1640–1645. doi:10.1161/CIRCULATIONAHA.109.192644.
2. Fahed G., Aoun L., Bou Zerdan M., et al. Metabolic syndrome: updates on pathophysiology and management in 2021. *Int J Mol Sci*. 2022;23(2):786. doi:10.3390/ijms23020786.
3. Lemieux I., Després J.P. Metabolic syndrome: past, present and future. *Nutrients*. 2020;12(11):3501. doi:10.3390/nu12113501.
4. Zheng Q., Gao X., Ruan X., et al. Are low carbohydrate diet interventions beneficial for metabolic syndrome and its components? A systematic review and meta-analysis of randomized controlled trials. *Int J Obes*. 2025;49(7):1252–1263. doi:10.1038/s41366-025-01822-5.
5. Patikorn C., Saidoung P., Pham T., et al. Effects of ketogenic diet on health outcomes: an umbrella review of meta-analyses of randomized clinical trials. *BMC Med*. 2023;21:196. doi:10.1186/s12916-023-02874-y.
6. Chen S., Su X., Feng Y., et al. Ketogenic diet and multiple health outcomes: an umbrella review of meta-analysis. *Nutrients*. 2023;15(19):4161. doi:10.3390/nu15194161.
7. Tian W., Cao S., Guan Y., et al. The effects of low-carbohydrate diet on glucose and lipid metabolism in overweight or obese patients with T2DM: a meta-analysis of randomized controlled trials. *Front Nutr*. 2024;11:1516086. doi:10.3389/fnut.2024.1516086.
8. Zhao J., Wei C., Gong F., Pang Z., Zhao H. Ketogenic diet-induced changes in adult lipid metabolism: a comprehensive systematic review and meta-regression of randomized controlled trials. *BMC Cardiovasc Disord*. 2026;26(1):520. doi:10.1186/s12872-026-05799-5.
9. Chang C., Liu Y., Rohani P., et al. The Impact of the Ketogenic Diet on the Lipid Profile in Adults: A Comprehensive Review and Meta-Regression Analysis of Randomized Controlled Trials. *Endocr Pract*. 2026;32(5):819–828. doi:10.1016/j.eprac.2026.01.009.