Human Metabolism's Reaction to a Low-Carbohydrate Diet

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Abstract. In recent years, as the quality of life has improved, the obesity problem has become more serious, affecting adults and children around the world, reaching epidemic proportions. Low-carbohydrate diets (LCDs) are widely popular among people and used by a wide range of patient groups for weight management. This review examines the complex interactions between human metabolism and LCDs, focusing on the effects on metabolism and personal health. Part One discusses the importance of carbohydrates in metabolism. The second part examines the metabolic effects of a low-carbohydrate diet. Part Three analyses the therapeutic implications of low-carbohydrate diets, highlighting their potential applications in weight loss and management, disease control and treatment, and supplementation for endurance athletes. Despite the remarkable results achieved so far, this paper finds that there are still many shortcomings. Although the impact of LCD on metabolism has been studied, the risk of long-term health effects needs to be further explored. Therefore, larger-scale, multi-center trials targeting different populations are needed to further evaluate the impact of LCD. Based on these conclusions, this article has important implications for healthcare professionals in providing personalized guidance that takes into account individual responses and circumstances.

Keywords: Obesity; metabolism; low-carbohydrate diet; health.

1. Introduction

Obesity is a prevalent, dangerous, and costly chronic illness that affects both adults and children. As economies and technologies advanced gradually, many nations lost interest in finding solutions to their food crises. People started becoming taller and heavier with the start of the Industrial Revolution, and by the end of the 20th century, the rate of obesity had nearly tripled worldwide. And the number of fat persons has surpassed that of non-obese ones. Over the years, obesity has become more common in all age categories and has become a global epidemic, irrespective of socioeconomic class or ethnicity. According to the WHO European Regional Obesity Report 2022, over one-third of youngsters (29 percent of boys and 27 percent of girls) and nearly 60% of adults suffer from overweight and obesity. According to the WHO European Regional Obesity Report 2022, over one-third of youngsters (29% of boys and 27% of girls) and nearly 60% of adults suffer from overweight and obesity [1].

Based on the WHO definition of obesity, a body mass index (BMI) over 25 is considered overweight, and over 30 is considered obese [2].

Overweight and obesity are defined as an abnormal or excessive accumulation of fat that poses a risk to health.

Obesity is not only a chronic disease in its own right but is most importantly strongly associated with the prevalence of cardiovascular disease (CVD) and diabetes, but also cancer and chronic diseases: including osteoarthritis, liver and kidney disease, sleep apnea and depression. Obesity contributes to the dysfunction of many organs, a decrease in the quality of life of people, serious diseases, and a higher mortality rate [3].

As health awareness among the population gradually deepens, the risks posed by a sedentary lifestyle and poor diet cannot be ignored. Therefore, various weight control strategies are gradually being tried. In addition to physical activity support, dietary adjustments are another well-liked option for weight management. However, there has always been disagreement and controversy over the optimal diet to maintain or lose weight. The potential of low-carbohydrate diets (LCDs) to treat and improve health has drawn a lot of interest. LDCs, in contrast to an ordinary diet, emphasises foods

high in fat and protein (e.g., meats, poultry, fish, shellfish, eggs, cheese, nuts, and seeds) and limits the intake of carbs, such as those found in grains, starchy vegetables, and fruits. Moreover, low-carb foods (such as fibre vegetables like spinach, kale, beets, and collard greens) should be consumed [4].

Three macronutrients are included in the foods: protein (4 kcal/g), fat (9 kcal/g), and carbs (4 kcal/g). According to a study on LCDs, the definition is shown in table 1.

Table 1. The definition of carbohydrate content [4].

Carbohydrate Content	Percentage (%) of Carbohydrate
Very low carbohydrate (20 to 50 g/day)	10%
Low carbohydrate (less than 130 g/day)	26%
Medium-carbohydrate	26%–44%
High carbohydrate	45% or higher

Therefore, diets with less than 130 g of carbohydrates per day (or less than 26 % of total calories in a 2000kcal diet) are classified as LCD. On the other hand, the number of calories from fat (55–65%) and protein (25–30%) accounts for a comparatively large portion of daily calorie consumption, with carbs making up 20% or less of the total.

This approach is used in the ketogenic diet, which is a type of low-carb diet. It is based on the idea that the body produces ketones, an alternative fuel, from stored fat when it is deprived of glucose. When very little in the way of carbs is taken, the body releases the glucose by first drawing it from the liver and briefly dissolving the muscles. The body starts using fat as its main fuel source after all of the stored glucose has been used up [5]. Weight loss occurs as a result of the burning of fat. The health indicators linked to overweight improve when weight is lost. On low-carb diets, the belly and liver account for a significant amount of the fat lost. This type of visceral fat is hazardous because it accumulates in and around organs, causing illness and inflammation. Considering low-carb diets are becoming more and more popular, it is important to comprehend the theory and principles underlying their dietary design to make sure that individuals control their weight in a way that promotes health.

The article aims to explore the complex relationships that exist between human metabolism and low-carbon diets, as well as the potential short- and long-term effects that these dietary patterns may have on metabolism, individual health, and the larger context of sustainable living.

2. Carbohydrates' Function in Metabolism

As one of the three main nutrients included in a human diet, carbohydrates are vital to the functioning of the human body. The process of breaking down carbohydrates starts when salivary amylase breaks down starch in the mouth and concludes when monosaccharides are absorbed into the small intestine's epithelium.

Carbohydrate foods are broken down into little pieces in the mouth during chewing, which starts the process of digestion. The saliva produced by the mouth's salivary glands coats the food particles. The straight and branched chain starches are broken down into smaller glucose chains termed dextrins and maltose by salivary amylase enzymes, which are produced by the saliva. Severe stomach peristaltic movements combine the carbs into a more uniform chyme mixture. The duodenum, the upper portion of the small intestine, receives this chyme gradually. After being stimulated, the pancreas releases pancreatic amylase, which breaks down the chyme into maltose and dextrin. The small intestinal wall thereafter starts to produce lactase, sucrase, and maltase. These enzymes further convert sugar into simple sugars or monosaccharides. The small intestine finally absorbs these carbohydrates [6].

2.1. Energy Source

Glucose, produced during the breakdown of carbohydrates, is subsequently delivered to cells and tissues to power a variety of metabolic functions. The liver and muscles store extra glucose as glycogen, which is used later for energy. Glycogen can be broken down to release glucose and

stabilize blood sugar levels when energy demands rise. To utilize glucose as fuel, the pancreas secretes the hormone insulin. Carbohydrates are broken down into glucose during digestion, and this glucose is subsequently transferred to cells and tissues to power different metabolic processes [7].

2.2. Blood Sugar Regulation

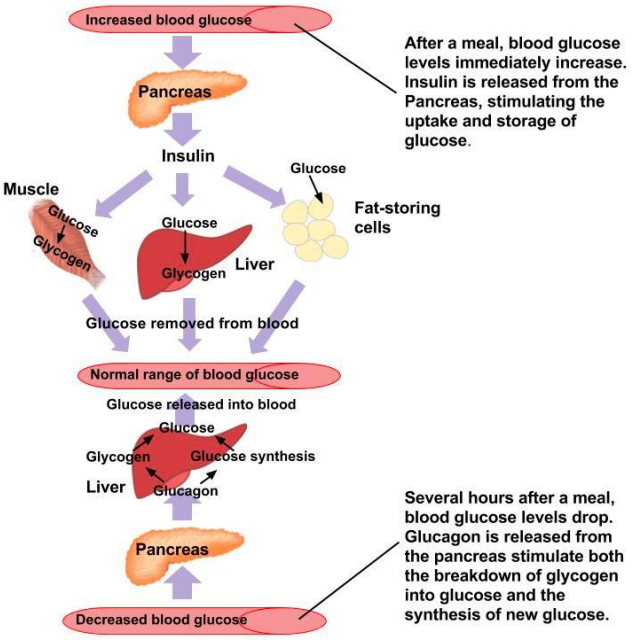

Fig. 1 The Regulation of Glucose [7].

As shown in figure 1, when blood glucose levels rise, the pancreas releases insulin to boost cellular glucose uptake, whereas glucagon encourages the release of stored glucose when levels fall.

2.3. Lipid Metabolism

The "fat-saving" action of glucose. This is so because high blood sugar causes the hormone insulin to be released, and insulin uses glucose instead of fats to make energy. Ketosis can also be avoided if blood glucose levels are high enough. Because they replace protein as a source of energy, carbohydrates enable the body to use amino acids for tissue growth and repair. Maintaining total body structure and muscle mass requires this.

2.4. Cellular Respiration

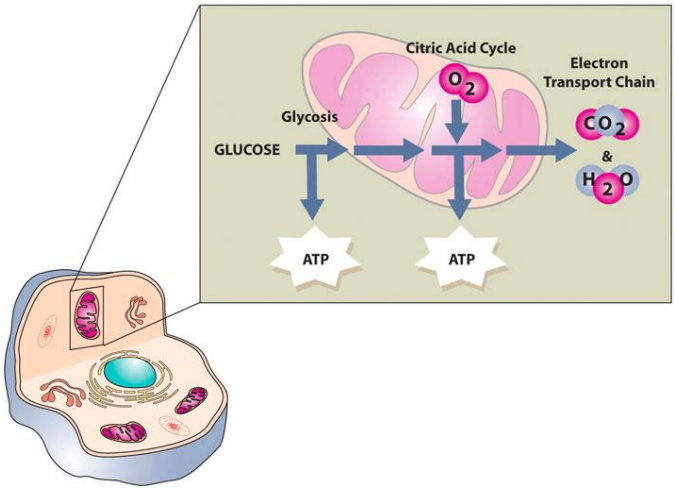

Fig. 2 The process of obtaining energy from glucose through cellular respiration [8].

As shown in figure 2, the process of producing significant amounts of ATP involves further breaking down glucose-derived pyruvate in the mitochondria [8].

2.5. Dietary Fibre

Bacteria in the large intestine break down some indigestible carbohydrates, or dietary fiber, into enzymes. Dietary fibers serve to control blood glucose levels and support healthy gut microbiota because they are digested in the gastrointestinal tract in far smaller amounts than other carbohydrate types. As a result, the rise in blood glucose after consuming them is smaller and slower [9].

3. The Influence of Low carbon on mMetabolism

As an illustration of a low-carb diet, the ketogenic diet allows the body to use fat as a source of energy by reducing carbs and increasing fat.

3.1. Enhanced Fat Metabolism

The body stores carbohydrates as glycogen, mostly in the muscles and liver. When glycogen stores are reduced by a low-carb diet, the body starts burning more fat for fuel since there are fewer carbs available for use as fuel. Increased fat metabolism results from the breakdown of stored fat into fatty acids and their use as fuel.

3.2. Ketosis

As shown in figure 3, when there is a shortage of glucose, the body turns to ketones as an alternate energy source, particularly for the brain. Without glucose, the liver may utilize lipids to make ketone bodies [10].

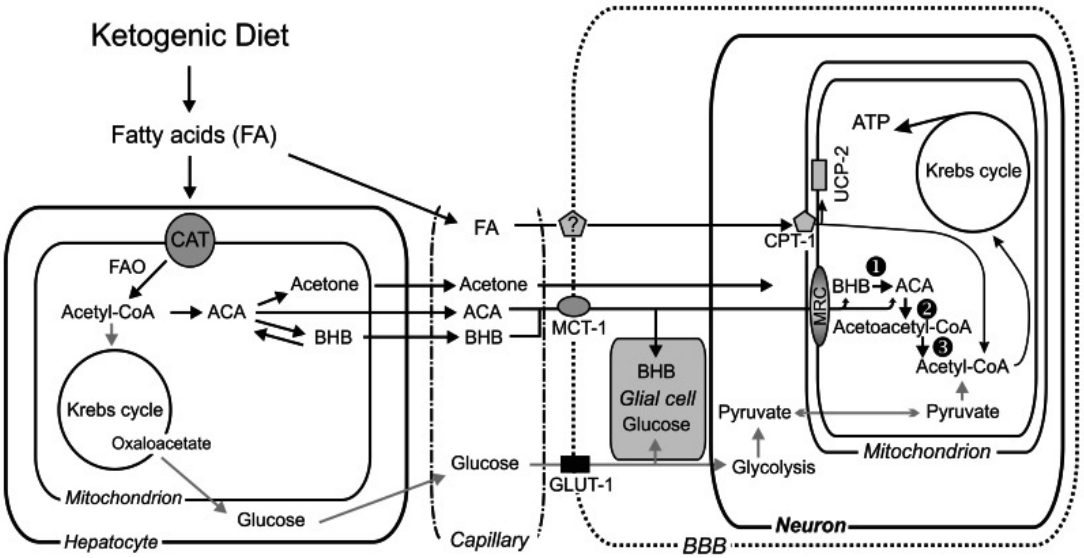

Fig. 3 Metabolic pathways of the human body on the ketogenic diet [10].

3.3. Increased insulin sensitivity

Hormones like insulin that drive hunger are lessened when carbs are ingested in moderation [11]. Blood sugar levels become steadier, and less insulin is needed by the body to regulate blood sugar when carbohydrate intake is decreased. While some forms of carbs are restricted in low-carb diets, foods high in fiber and non-starchy vegetables are typically included. It has been demonstrated that dietary fiber improves insulin sensitivity and aids in blood sugar regulation [11].

3.4. Increased Energy Expenditure and Satisfaction

A study involving 164 persons with a BMI of 25 or more, ages ranging from 18 to 65, examined the impact of varying carbohydrate-to-fat ratios on overall energy expenditure. According to the experiment's findings, for every 10% decrease in the amount of carbohydrates consumed, overall energy expenditure (52 kcal/d) increased. In comparison to the high-carb group, the medium- and

low-carb groups expended more energy overall, averaging 91 kcal/d and 209 kcal/d, respectively [12]. Less energy was burnt due to increased satiety. In contrast to a low-fat diet, Hu et al. showed that a low-carb diet enhanced peptide YY, a satiety signal, indicating improved appetite control in the low-carb group [13]. Low-carb diets typically include fat and protein as components that aid in satiety. This would cause a natural reduction in caloric intake, which would have an impact on the balance of energy and possibly aid in weight loss.

People are embracing the popular low-carb diet to treat specific conditions or lose weight since it restricts calories and increases energy expenditure. However, just as individuals differ in their microbiomes, genetic makeup, and reactions to certain foods, so do foods. A low-carb diet's impact on metabolism differs from person to person.

4. Clinic Significant

4.1. Weight Loss and Management

The use of LCD reduces glucose availability to the liver while increasing lipolysis. Plasma insulin levels are also reduced, removing the motivation to store fat in adipose tissue, and LCDs can considerably reduce body fat, at least in the short term. A low-carbohydrate diet reduces appetite and calorie intake, which helps in weight loss [14].

4.2. Disease Control and Treatment

Reducing carbohydrate intake improves glycemic control, which can lead to a large reduction in the amount of insulin and oral medicine used, as well as a decrease in glycated hemoglobin. A low-carbohydrate diet can improve type 2 diabetes remission and is often safe. Low-carbohydrate diets may improve lipid profiles in some people by boosting HDL (high-density lipoprotein) cholesterol and decreasing triglycerides. Furthermore, high fiber consumption has been linked to lower cholesterol levels and a lower risk of heart disease. Surprisingly, the addition of a low-carb diet promises further benefits in cancer treatment [9,15].

Low-carbohydrate diets may benefit endurance athletes, particularly in terms of fat adaption [16].

Nevertheless, consistent concentration, drive, courage, and commitment are required for any successful behavior change. While habituation is feasible, long-term behavioral change is sometimes difficult. It is critical to understand that the benefits of this diet are accompanied by unavoidable limits.

Low-carb diets help individuals lose weight in the short term, but they have no different long-term effects from high-carb diets. Additionally, successful LCD adoption frequently results in stringent food restrictions, with the danger of nutritional deficiencies. Low-carbohydrate diets can result in decreased fiber consumption, which raises the risk of constipation, harms bacteria in the gut, and increases the risk of colon cancer [17]. A high protein and saturated fat intake may worsen disease progression in patients with specific underlying illnesses (e.g., excessive uric acid levels, renal failure, or vascular disease). The most restrictive ketogenic diets used to treat epilepsy can cause fatigue, headaches, nausea, constipation, hypoglycemia, and acidosis, especially in the first few days to weeks after starting the diet. Dehydration, hepatitis, pancreatitis, hypertriglyceridemia, hyperuricemia, hypercholesterolemia, hypomagnesemia, and hyponatremia are all possible side effects. Long-term consequences could include decreased bone density, renal stones, cardiomyopathy, anemia, and optic neuropathy. Ketogenic diets are poorly accepted and unsustainable for many people in the long run. Low-carbohydrate diets are also linked to an increased risk of death from any cause. Because of these issues, while some studies have shown positive results, it cannot be assumed that they are applicable to the general population; especially given that people with diabetes or obesity frequently have other comorbidities, such as dyslipidemia and cardiovascular disease, and that strict medical and nutritional supervision is required to comply [18,19].

5. Conclusion

Despite extensive research into the effects of LCDs on humans, knowledge about human diet remains scarce, and the long-term health hazards associated with low-carbohydrate diets are unknown. Most studies had limitations due to small sample sizes, limited intervention duration, and high participant dropout rates. Larger, prospective, multicenter trials are clearly needed to study the effects of LCDs. This diet may help with weight loss, improved insulin sensitivity, cardiovascular health, and cancer prevention. But because there are huge differences between individuals, personalized advice from a healthcare professional is needed.

Although this article provides a detailed analysis and comparison of the impact of LCDs, it does not mention the complexity of personal health disorders and aspects other than body metabolism, such as the impact on human mental health or emotional changes. The long-term persistence of LCDs and their effects on different populations require further study. Future research should prioritize long-term studies to examine the long-term effects of low-carbohydrate diets on health outcomes.

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