

The Effect of The Ketogenic Diet on Fitness Activities and The Both Positive and Negative Impact on Body

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Abstract. The ketogenic diet has certain effect that can effectively help people lose their weight in a short time, and the composition which is eliminated the most is fat. Studies have experimented on different kind of ketogenic diet, their function, their impact on physical activities and impact on human body. Some basic logic including the ketosis—a state of metabolism when the ketone is used as the primary source of energy, ketone body—achieved then the fatty acid is decomposed, nutrients intake—especially the three main ones—carbohydrate, protein and fat, and caloric restriction, and the importance of micronutrients. This article will primarily contain an introduction about the history of ketogenic diet—the relationship of fasting with ketogenic diet, its function—both on weight loss and the effectiveness of the protection on motor function. The relationship between ketogenic and physical performance—both aerobic exercises and anaerobic exercises. The last part is its impact on human body for both short term and long term and include a conclusion.

Keywords: Ketogenic Diet; Weight Loss; Physical Performance.

1. Introduction

Ketogenic diet (KD) is a type of diet which contains low level of carbohydrate intake, plenty amount of proteins but extraordinary amount of fat intake [1]. ketogenic diet is quite popular among many bodybuilders, it is able to help people who work out gain muscles and reduce fat level on their body. With people's increasing demand beauty, which is mainly losing weight at the same time preserving the amount of skeletal muscle, ketogenic diet became popular worldwide. Some people have shown their concern about whether the high fat intake will result in the increase of their body fat rate, however, this low carbohydrate and high fat intake KD actually can decrease body fat rate through specific mechanism. Many people have exploited wrong ketogenic diet and show negative impact on body. Some people believe that the correct use of the KD is an effective method to loss body weight. There is also a rising concern that the physical performance of people who use KD, whether KD has a positive or negative impact on both aerobic and anaerobic physical activities. This is quite significant for those athletes including bodybuilders who are exploiting KD. Some athletes ignore the side effect of such diet, as a result, their sport career end before the expectation. The history of the ketogenic diet showed that the KD had a special relationship with fasting—which is considered the precursor of KD. Initially, the fasting method was used to treat epilepsy for kids. Function of using ketogenic diet on human body, different kinds of impact on body. This article will first discuss the history of ketogenic diet and the history of the relation between KD and fasting, and the function it has for human body including the theoretical information. A brief review of the effects of KD on aerobic and anaerobic exercises and the impact on human body will also be provided. Eventually, both the upsides and downsides of this diet in both short term and long term will also be discussed.

2. History of Ketogenic Diet

2.1. The Precursor of Ketogenic Diet - Fasting

In 1911, in order to find a solution to epilepsy, two Parisian physician, Gulep and Marie, first experimented the effect of starvation on epilepsy [2]. 20 adults and children were fasting, and the result showed that the seizures became less serious while they were fasting. However, there was not any specific detail documented. Also in the early 20th century, a magazine called Physical Culture

which was written by Bernarr Macfadden was published. Macfadden focused on how to become health and strong for the sick men and women, and also claimed that for every illness or cancer, experiencing starvation for 3 days to 3 weeks will definitely show some mitigation. At the time the First World War ended, his magazine' circulation had reached 500000. Dr. Hugh W. Conklin, the assistant of Macfadden, exploited fasting as the method for a variety of illness, drew attention to another elite in epilepsy study. In New York Presbyterian Hospital, H. Rawle Geyelin is an endocrinologist who reported his own experience of fasting as the treatment of epilepsy to The American Medical Association Convention in 1921. The first person to make document on the topic of the cognitive improvement when a person is fasting is Dr. Geyelin. Drs. Cobb and Lennox, people who studied the influences of using fasting as a solution of seizures in Harvard Medical School, were the first to discovered that the seizures will improve in 2-3 days after fasting. Lennox attributed this improvement to the change of body metabolism due to the fasting, and the inexistence of food and the scarcity of carbohydrate compel the body to burn acid-forming fat [3].

2.2. The Origin and Development of Ketogenic Diet

In 1921, there were two significant findings figured out. First, cetone and beta-hydroxybutyric acid appear when using the fasting method or the diet that contains extremely low proportion of carbohydrate and massive amount of fat [3]. This was discovered by Woodyatt. The point is that these benefits could be obtained by other ways, that is, by using ketogenic diet, asserted by Wilder, who studied health problems in Mayo Clinic. He mentioned the point that KD(ketogenic diet) was able to serve as the same function as fasting when treating epilepsy, but healthier and more durable, which means the KD can be used for a longer time. By contrast, simple fasting did have the effects, but there will be some negative impact if fasting continues for a relatively long period. Then, Wilder had continued to document patients who exploited such ketone-producing diet and obtained the word "ketogenic diet." However, in 1938, as the diphenylhydantoin (DPH) was discovered, most of the physicians and doctors shifted their attention to the DPH [4]. As a result, the new antiepileptic drugs and therapy replaced the KD, which was given up by many scientists. Dr. Peter Huttenlocher introduced a medium-chain triglyceride oil diet in 1971 in the University of Chicago, in order to make the KD more acceptable for public. Nevertheless, this innovation did not help KD with its revitalization, fewer kids were placed on KD to treat epilepsy, and scientists believed that it is the antiepileptic drugs that gave them hope to eliminate epilepsy. However, this trend ended when NBC-TV's Dateline started a program on such experimental method. An example of a boy called Charlie who was 2 years old and had serious seizures was showed in this program. He was introduced to a hospital and treated with KD. Consequently, he got rid of epilepsy in a fairly short of time and his father launched The Charlie Foundation which spread a massive number of videos which documented the cure process and information about KD, and it is the first time that the effectiveness and evidence of KD was supported. "First Do No Harm", a film Charlie's father directed through Charlie's treatment, was influential. This event had truly made KD back to historical stage.

3. Function of Ketogenic Diet

3.1. Weight Loss

From 1960s, the KD had been considered an effective way to treat obesity. Primarily, the ketogenic diet contains extremely low ratio of carbohydrate, moderate or a bit more protein and the remaining energy requirements all come from the source of fat. In numerical account, the percentage of fat can be as high as 60, and the protein and carbohydrates are respectively 30% and 10%. For instance, a 1000 kcal diet may only consist of about 15g of carbohydrates [5]. Many diets also have fairly low amount of carbohydrates, but they are not ketogenic diet. At the same time, a ketogenic diet has to make sure that there is a huge amount of fat intake as a source of energy. Even though people paid a lot of attention to this low-carbohydrate diet which makes it possible for rapid weight loss in recent years, the standard of "low-carbohydrate" maintains confused, or the specific amount of

carbohydrates must be reduced to cause ketosis. Ketosis is a metabolic state characterized by elevated levels of ketone bodies in the blood or urine. Physiological ketosis is a normal response to low glucose availability, such as low-carbohydrates diet or fasting, that provides an additional energy source for the brain in the form of ketones. In physiological ketosis, ketones in the blood are elevated above baseline levels, but the body's acid-base homeostasis is maintained. In such kind of state, the body starts to lose weight in several mechanisms. The main part of the loss of weight at the beginning is because of diuresis, which means simply high in urination. The two causes are ketonuria and glycogen depletion(GD), that generates the renal sodium and water reduction. There are 100g and 400g of glycogen are stored respectively in liver and muscles, and for each of the gram of glycogen, there are around 2g of water is stored with. In short, for the initial weight loss of body in KD, the main composition of losing is simply water [6]. Another hypothesis states that the ketone ketogenic low-carbohydrate diet is able to suppress appetite, and ketogenic low-carbohydrate diet has a “metabolic advantage”, as it is capable of necessitating increased gluconeogenesis and up-regulating mitochondrial uncoupling proteins with a resultant wasting of ATP as heat. Additionally, the KD helps loss weight by limiting the choices of carbohydrate, which decreases the palatability and the satiating effect of relatively high protein intake, and increases the thermogenic effect of protein. In conclusion, weight loss is associated with the restriction of caloric intake, long period of ketogenic diet duration and base weight, but not associated with carbohydrate content. For recent years, KD has received significant attention and popularity. A number of people including athletes who want to lose weight (especially lose fat) have employed KD and combined with their physical exercises.

3.2. Improve Motor Function

Ketogenic diet can increase ketone body production and its concentration in body, offering the body with a new energy source that boost oxidative mitochondrial metabolism. In addition to its profound impact on neuro-metabolism and bioenergetics, the neuroprotective effect of specific polyunsaturated fatty acids and ketone body involves pleiotropic mechanisms [7]. The KD has protective effect on neuromuscular system in different mechanisms. First of all, KD is able to directly induce metabolism shift by high level of ketone body in blood and the restriction of carbohydrate intake. Furthermore, KD can also alter nutrient-integrating pathway, like the mTOR pathway. Eventually, ketogenic diet has suggested roles—effects on neurotransmission, oxidative stress and inflammatory mechanisms. Fig 1 shows the cellular mechanisms of KD [7].

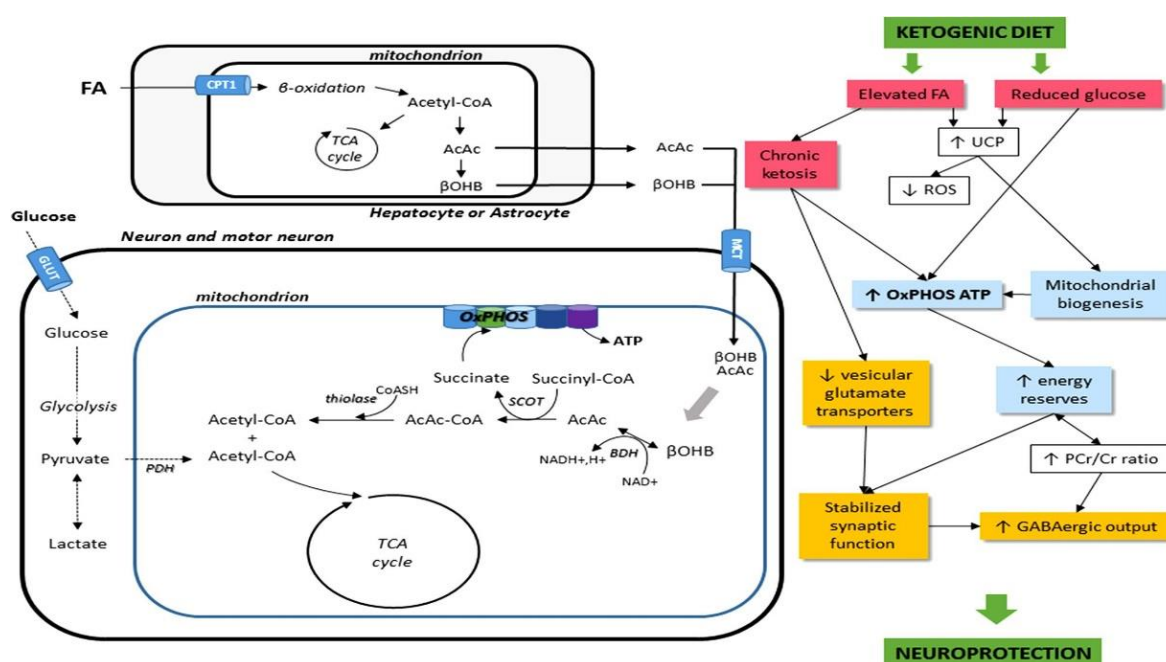


Fig. 1 Schematic illustration of the main cellular mechanisms in the KD on the neuromuscular system [7]

4. Ketogenic Diet and Physical Fitness

4.1. Preservation of Skeletal Muscle

KD has the ability to prevent the loss of muscle even though it contains an exceedingly low amount of carbohydrate. This is also a main reason of why main body builders exploit KD while they are preparing for a contest. There are several mechanisms illustrating this. The one that is commonly known and comprehended asserts that the extraordinarily high fat amount will minimize the loss of muscle, since when using KD for a period of time, the body gets used to burn fat instead of muscle or glucose (come from carbohydrate) as a main source of energy. As a result, the burning of muscles as energy is decreased. The level of insulin determines whether to store the extra energy as fat or to burn fat as energy [8].

In addition, KD indeed has low intake of carbohydrate, but its protein which is the (most significant factor of gaining of skeletal muscle) intake relatively high than normal diet. This guarantees that skeletal muscles are in a stable condition. For the bodybuilders, such effect is exactly what they want, since they have to make sure the extremely low body fat rate at the same time containing more muscles. Another mechanism suggests that the liver generates ketone bodies while using KD and the KBs flow from the liver to extra-hepatic tissues to be used as energy source. Furthermore, the KBs are able to set a limit in muscle breakdown. Study has proved that beta-hydroxybutyrate which is a major KBs can decrease leucine oxidation and enhance protein synthesis. In terms of the last plausible mechanism, it is about growth hormone [9]. GH plays a crucial role in regulating human body's development, and it is a protein anabolic hormone which promotes protein synthesis. As KD only has few carbohydrates intake which leads to the low blood sugar level, and the scarcity of sugar in blood can increase the secretion of GH, which contributes to the muscle growth.

4.2. The Effects of Ketogenic Diet on Aerobic Endurance Exercise

There is a tremendous number of experiments and studies which focused on the effects of KD on aerobic activities in the previous years, and the majority of the investigations included the adult athletes, especially male. In terms of their diet, the ranges of percentage of the three primary nutrients are carbohydrate 3.5-15%, protein 15-29% and fat 63-80%. Nearly all the people who participated in such experiments showed some features in common. Inevitably, the level of the KBs in their body increased, the weight and the body fat rate decreased a lot—all are some basic and positive improvements. Although there is an enormous decline in RER (respiratory exchange rate), the KD does not have an obvious modification on the testers' entire period to exhaustion, the oxygen uptake in maximum or endurance performance. In fact, some studies even showed that the testers tend to spend a shorter time to become exhausted. So far, studies on the effects of KD on endurance performance are limited and some obtain different data. A study had shown that people with obesity following a KD would lose enormous weight and fat, and at the same time enhanced their endurance activity performance. Nonetheless, this result happens in a normal low-carbohydrate diet too, so this consequence might not necessarily happen only in KD [10].

4.3. The Effects of Ketogenic Diet on Anaerobic Exercise

Anaerobic exercise is a set of sport that only lasts within only 2 minutes but has quite high intensity. The phosphagen system and the lactic acid system in human body are responsible for the main energy source for anaerobic activities, in which the determinant is the glycogen in skeletal muscles. Resistance training is one of the most classical anaerobic activities. In resistance training, high pressure is put on muscles, so the muscles need to contract and exert force on bones. As a result, the muscle fibers are broken. In order to fix and repair the muscle fibers, a number of amino acids are required for protein synthesis. In KD, the amounts of proteins are plentiful which prevent the deficiency of amino acid. However, owing to the lack of carbohydrate intake in KD, the amino acids become increasingly indispensable and the body lacks glycogen restoration, which will negatively influence the performance on anaerobic exercises. Fig 2 shows the energy sources when using KD.

Studies have done on such topic, after 6-12 weeks of KD intervention, there is no significant alteration of participants' power. However, many have shown that the relative power has increased to different degree. The main reason for this is the weight loss, due to the decline of the base of body mass, which is a common subsequence of intervention KD [12].

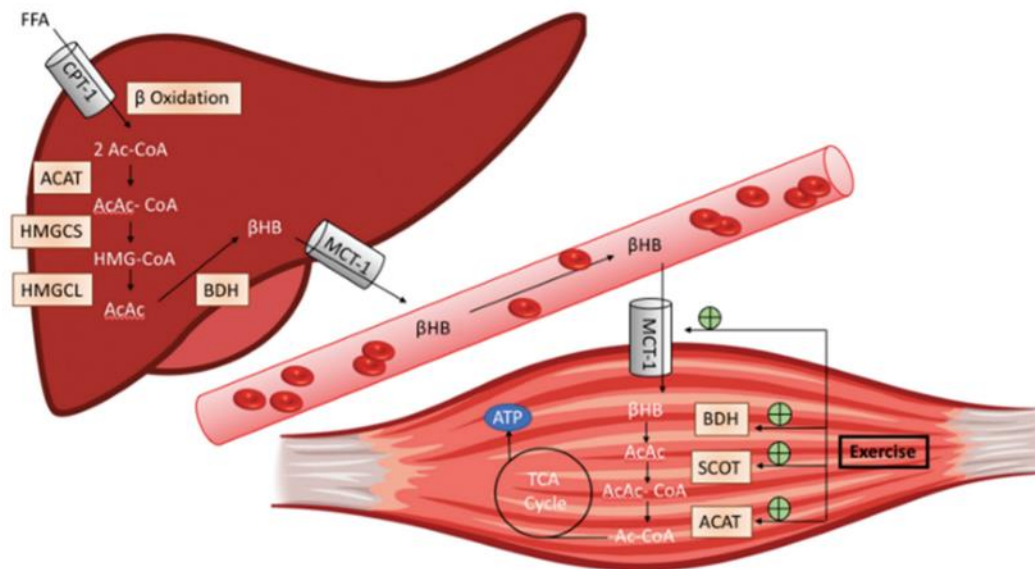


Fig. 2 Overview of the metabolism of ketone bodies (KBs) in liver and skeletal muscle [11]

5. The Impact of Ketogenic Diet on Human Body

5.1. Potential Risks - Short Run

Due to the fact that KD has relatively high protein intake, there might be some damage on kidney owing to the fact that the nitrogen excretion is high while protein metabolism. This type of damage can lead to the increase of the pressure of c. There is not plenty of research on this topic, but many same experiments have been done on animals.

If using the KD for long term, it will just work as a serious factor for kidney stone. However, most people exploiting KD for weight loss, and the efficiency is really high. As a result, most people will just use KD for no longer than several weeks, when they have reached their target weight, they will stop the KD. Many studies have shown that the creatinine has been increased during the KD intervention, but it is still within the normal range [13]. Furthermore, constipation and nausea are some of the common symptoms of KD. A study including obese candidates who have exploited KD for more than 2 weeks showed that the number of participants in KD group have such inverse effects numbered twice as the controlled group. Even though the frequency of the side effects has been reduced during the experiment, the final result still reported that a small portion of the candidates had the problem of constipation and nausea.

5.2. Potential Risks - Long Run

The majority of information about KD's long term effects regards the use of KD in kids' epilepsy treatment. Studies on the effects of KD on adults are limited. It was reported that using KD for more than several months would cause inadequate nutrition, especially lack in fiber, folate, iron, vitamins and etc. However, a study done by Stock and Yudkin suggested that a two-week KD would not lead to the deficiency in such micronutrient, which indicated that the longer time the KD was used, the more serious of the deficiency of vitamins and other nutrients. With the time of KD intervention increases, the side effects will be worse and worse, eventually goes into a negative cycle. A study was down at the Kuwait University with 83 obese candidates which included 39 male and 44 female, and the KD last for 24 months. The BMI of them was 35.9 ± 1.2 kg/m² and 39.4 ± 1.0 kg/m²,

respectively. The mean age for men and women was 42.6 ± 1.7 years and 40.6 ± 1.6 years. Besides the usual KD, the candidates also received micronutrients according to Table 1.

The results showed that the body mass, BMI, level of LDL, level of triglyceride have a significant decrease, at the same time, level of HDL, level of creatinine have increased. There were only a few candidates who had some side effects which resembles the problem of deficiency of micronutrients, which successfully implied that the overall diet is the crucial factor of having side effects. Beside the normal intake of carbohydrates, protein and fat in KD, the correct amounts of micronutrients can prevent many negative impacts on body when using the KD for long term [14].

Table 1. The micronutrients for candidates.

Name of the micronutrients	Dosage
Para-aminobenzoic acid	30mg
Vitamin B1	15mg
Vitamin B2	3mg
Vitamin B5	25mg
Vitamin B3	3mg
Vitamin B6	5mg
Vitamin B12	10mg
Biotin	5 μ g
Folic acid	100 μ g
Vitamin C	60mg
Vitamin A	0.6mg
Vitamin D	5 μ g
Vitamin E	10mg

6. Conclusion

The result indicates that the KD is quite justifiable for weight loss—not only because the relatively long history which provide the fundament of practicability, but also the plenty of studies which make sure the effectiveness of KD for losing weight. However, exploiting such low-carbohydrate diet has certain negative influences like constipation, damage on kidney—even the appearance of kidney stone if using KD for long run and increasing the pressure of glomerular. This point helps people realize that besides the three main nutrients, micronutrients are significant to avoid such enormous side effects when using KD for long term. According to the last experiments mentioned above, under a micronutrients-adequate circumstance, KD has played a significant role for obese people with a relatively few side effects and the low possibility of gaining weight again. Especially for BB(bodybuilders), KD is able to decrease body fat rate with certain mechanism that make body get used to consume fat as the first energy source, at the same time minimizes the skeletal muscle loss, which exactly match the requirements for bodybuilding contests. In addition, KD has also contributed to the motor function in several mechanisms by the protective effect of neuromuscular system—inducing metabolism shift, modifying the pathway of the integrating of nutrient and the effects on neurotransmission, oxidative stress and inflammatory mechanism.

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