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# Effect of Ketogenic Diet on Physical Activities and Body Composition-A Review

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**Abstract**

**Problem:** Despite widespread awareness of the appropriate countermeasures, obes remains a major global public health concern.

**Approach:** Ketogenic diets are becoming more popular among various dietary strategies for controlling body-mass and promoting fat mass loss. KD significantly lowers daily carbohydrate intake. Increased fatty acid utilisation follows, which raises blood ketone bodies (acetone, 3-β-hydroxybutyrate, and acetoacetate) and, consequently, metabolic ketosis. Studies on nutritional interventions have traditionally concentrated on lowering dietary fat, but the long-term benefits have been scant or inconsistent.

**Findings:** This review studies the effects of KD on body composition improvements and BM reduction in inactive persons when paired with various exercise modalities (either resistance training or endurance training) in athletes and obese adults.

Relevant studies were found by doing a literature search from 1921 to March 2024 using the databases Medline, Google Scholar, PubMed, Web of Science, Scopus, and Sport discus.

**Conclusion:**

Based on the existing research, KD are therefore a useful strategy for reducing body mass and BM in both obese individuals and athletes. These positive effects are mostly due to KD's appetite suppressant properties, which may reduce daily calorie consumption. In terms of body mass and fat loss in an isoenergetic situation, KD does not offer any more benefits than non-KD in obese and athletic groups. It seems that FFM decreases in obese, sedentary individuals are at least as significant as those seen following low-fat diets. Resistance-trained individuals appear to experience an FFM loss in lean mass when adhering to a KD. In contrast, individuals with endurance training demonstrate more effective FFM-preserving benefits from KD than those with resistance training.

Key words: Ketogenic diet, Sport, Athletes, Body-composition, Resistance-training, Endurance-training, Obesity.

**Abbreviations:** Body-fat-percentage (BFP); AMPK (AMP-activated protein kinase); AcAc (acetoacetate); BHB (3-β-hydroxybutyrate); body mass (BM); fat-free mass (FFM); fat mass (FM); growth hormone (GH); endurance training (ET); IGF-1 (insulin-like growth factor-1) and KB (ketone body) are acronyms for high-intensity interval training. Low-carbohydrate-diet (LCD); low-fat-diet (FFD); ketogenic diet (KD) MPB, the breakdown of muscle proteins. (RT)Resistance-training; and (MPS)Muscle protein synthesis.

## INTRODUCTION

The ketogenic diet (KD) is a nutritional plan that consists of high-fat and enough protein content but insufficient levels of carbs for metabolic demands (G20 g d-1 or 5% of total daily energy intake (1)), forcing the body to use fat as a primary fuel source. The original KD was developed with a 4:1 lipid: nonlipid ratio, with fat accounting for 80% of daily energy consumption, protein for 15%, and carbohydrates for 5%.

Many adjustments have been made to the original KD, such as decreasing the lipid-to-nonlipid ratio or allowing unlimited daily energy (in kilojoules) intake with protein and fat. The Cahill group's pioneering studies on fasting (2,3) provide the majority of our knowledge about the metabolic aspects of KD; in fact, fasting (consuming no or minimal amounts of food and caloric beverages for periods ranging from 12 hours to 3 weeks (4)) induces a specific metabolic state known as ketosis.

However, overall performance appears to be unaffected provided athletes are able to maintain an acceptable total energy and macronutrient intake, a correct sleep length and quality, and adapt the timing of the training load, despite considerable interindividual variances (5,6).

The following spring, accompanied by 12 Inuit (indigenous circumpolar people), they launched a more than 5000-kilometre sled trek, eventually returning to Camp Daly on March 4, 1880, over a year later (7).

Lt. Schwatka wrote in his diary, "When first placed fully on the diet of reindeer meat, it is inadequate to properly fuel the system, and there is an evident weakness and inability to do harsh, exertive, tiring excursions." However, this soon passes away in the course of two to three weeks (8).

Years later, Vilhajalmur Stefansson, an anthropologist, embarked on a journey to explore the Arctic mainland and learn about the language and culture of the Inuit people. Throughout his travels, Stefansson conducted experiments on himself using the traditional Inuit diet, which consists of 15–20 percent protein and 80–85% fat for energy. He noticed no issues (9). After these earlier reports, however, the study of KD seems to have sunk into oblivion until the 1920s when it experienced a ‘‘renaissance’’ as a therapy for epilepsy (38). Interest against waned with the introduction of pharmaceutical therapy for epilepsy, but it has been reawakened recently because of the severe side effects of pharmacological treatments (10).

Its usefulness in treating several illnesses, including obesity, polycystic ovarian syndrome, diabetes, cancer, and neurological disorders, has also been re-evaluated (11-13). Most studies on KD in more recent times have focused on weight/fat loss (14). Surprisingly, not many researches have looked at the connection between KD and athletic performance up to this point. We believe that KD can be applied to sports in two primary ways: first, it can be used to reduce weight more naturally in sports where weight is split into categories (15); second, it may have a favourable impact on endurance performance, which is surprising given certain research from the early 1980s (1).

**Literature search**

Using the databases Medline, Google Scholar, PubMed, Web of Science, Scopus, and Sport Reference, a literature search from 1921 to March 2024 yielded up pertinent papers. Search terms used to find relevant articles included "ketogenic diet," "very-low-carbohydrate-high-fat diet," "carbohydrate restricted diet," "VLCD," "body composition," "weight," "fat mass," "fat-free mass," "lean body mass," "muscle mass," "keto-adaptation," "athletes," "obese-obesity," "overweight," "resistance-training," "strength-training," and "HIIT."

All qualifying studies were carried out in English. The review's inclusion criteria focused on how KD affected changes in body fat, lean mass, and body mass reduction when used alone or in combination with exercise. Only trials utilising diets with <50 g/d and/or <5% of carbohydrates were included in this review, and throughout the paper, we will refer to a KD in an all-capitals manner.

## Effects of KD on body fat and body weight:

The evidence for the use of KD in weight loss is indisputably robust (14), but the exact processes by which it works remain a topic of controversy. Several explanations have been offered, according to one, "physiological ketosis" may be an "expensive" process that leads to a "waste of energy" compared to other forms of diets, and hence more effective weight loss.

The metabolic changes that occur during a KD may provide some evidence to support the "expensive" concept for weight loss. The brain's metabolism requires about 10g of glucose per day; in the initial phase of KD, roughly 16% of glucose comes from glycerol and the majority (60-65g) from proteins via gluconeogenesis. Gluconeogenesis is energy intensive and has been calculated to consume 330-360 kJ d-1 (16). Even if the usage of tissue amino acids as a source of glucose is important in the initial days of fasting, its value eventually declines; also, the protein supply consumed during a ketogenic diet "preserves," as demonstrated, lean body mass (17,18).

However, there is little clear evidence to support the idea, and a recent study (19) suggests that there may be no changes in resting energy expenditure during or after a KD. Another option is that enhanced weight loss is induced by appetite suppression as a result of the stronger satiety impact of proteins, which may also include changes in appetite hormone levels and/or a direct appetite suppression action of the KB themselves (20). The following is a summary of the different reasons why KD for weight loss works, with the strongest evidence coming first: (19)

1. Appetite suppression: protein satiety, impacts on appetite-related hormones including ghrelin, and possibly a direct appetite-blocking effect of KB.
2. decreased lipogenesis and enhanced fat oxidation.
3. A lower respiratory quotient may imply improve metabolic efficiency in fat oxidation.
4. Thermic impact of proteins and enhanced energy utilization by gluconeogenesis

**Effects of KD on body Composition**

Exercise's effects on body composition are mostly explained by the control of genes, hormone levels, and metabolic pathways (21-23). Additionally, RT produces better gains in muscular strength and bulk (24,25).

In order to improve muscle responses to exercise, current sports nutrition guidelines recommend carbohydrate-based or periodized carbohydrate-based diets (26-28). Feeding carbohydrates may be crucial for enhancing body composition and recuperation in people with resistance and endurance training (29,30).For instance, it's been proposed that carbs may enhance muscle growth in resistance-trained athletes by increasing their insulin response. Insulin specifically encourages anti-catabolic effects in muscle, which modifies the protein balance in favour of anabolism (31). Co-infusion of insulin and amino acids improves muscle uptake of amino acids (32-34), and it may raise MPS (35). Results from a study by Bird et al. showed that 12 weeks of carbohydrate + essential amino acid diet increases muscle anabolism after RT more than either of the two nutrients eaten alone (36). Nonetheless, because of their alleged positive effects on body composition, low-carb and high-fat methods like KD have been increasingly popular in recent years (37,38). Similar to untrained people, athletes may find that a KD is an efficient BM and FM loss approach (39).

Ad libitum trials primarily demonstrated the anti-obesity advantages of KD in trained persons (40,41). A resulting energy deficit brought about by the KD, as well as increased feelings of fullness and a decrease in overall food intake, may likely account for the BM and/or FM loss (40). On the other hand, other data indicates that combining exercise with a KD increased fat oxidation and the creation of ATP from fat (42,43). These results highlight the beneficial effects of KD on mitochondrial activity and the effectiveness of fat oxidation in athletes. Concerns regarding FFM reduction in athletes engaging in high-intensity exercise persist, nevertheless (44,45). Studies have demonstrated that a combination of exercise and KD is more effective in reducing body mass and fat mass, particularly when done ad libitum (46-49).

The fastest-oxidizing substrates for muscle tissue are KB, BHB, and AcAc. In contrast to severe dietary restriction, KD gives athletes enough protein and energy. As a result, KD prevents protein shortage but instead causes a "fasting-like" condition that modifies metabolic pathways (38,17). While both KD and fasting cause elevated serum FFA and glycogen depletion, the physiological changes that occur after a KD differ from those that occur during fasting. Adipose tissue breakdown cannot explain losses of the scale experienced during fasting; instead, they most likely indicate considerable lean tissue catabolism (50). These variations may result in variations in KB concentrations since KB is crucial in controlling the utilisation of muscle substrates (51-53). KB restrains MPB in some way (54). According to Thomsen et al., BHB has strong anti-catabolic effects on muscle across the body; in muscle, decrease of MPB outweighs inhibition of MPS (55).

Long-term fasting physical activity also promotes ketogenesis and causes post-exercise hyperketonaemia, in addition to dietary treatments (56-58).

For instance, following two hours of exercise done while fasting overnight, KB concentrations can rise to approximately 0·5–1·0 mmol/l. These concentrations then peak during the early stages of post-exercise recovery at 1–4 mmol/l (58-60). The amount and intensity of exercise, together with dietary status, all affect how much hyperketonaemia is caused by exercise both during and after exercise (56,57). In addition to increasing fat oxidation during exercise, alternative fuelling mechanisms based on adaptation to a KD may help protect the body's limited glycogen stores (61). KD has also been utilised to boost the oxidation of fat during exercise. Additionally, this raises the synthesis of KB, which could give the brain and muscles another energy substrate (62).

To sum up, KD can be a useful strategy for BM and FM loss in people who have trained for resistance or endurance. However, depending on the kind and level of exercise used, it can have different impacts on muscle mass. We will go into more detail on body composition changes in athletes doing endurance training and adhering to KD later in this work. (63)

**KD and sports**

Even while there are still numerous worries concerning the use of KD in sports (64), several promising studies on KD and performance (17,18) highlight the necessity for a thorough understanding of its mechanisms of action for sporting reasons. This kind of diet seems to have a few advantages over other extreme energy-restricted "crash" diets. The latter, even when followed for a

short while, can lead to situations where the body is malnourished for essential nutrients (vitamins, minerals, essential fatty acids, and amino acids), as well as other macronutrients that aid in the regulation of inflammatory processes and oxidative stress. (38)
With the exception of extremely low carbohydrate levels (G20 g carbohydrates d-1), an energy-sufficient KD diet with an adequate amount of protein (minimum 1.3Y1.5 g kg-1 of body weight) is not an "extreme" diet. As a result, it does not cause metabolic imbalances, which can have irreversible effects if nutrient-deficient weight loss diets are repeated frequently. (38)

## KD and Resistance Training

Paying particular attention to how short bursts of KD affect power and strength performance is warranted. As was previously mentioned, a safe weight loss strategy that doesn't affect performance can be a useful and valid tool for athletes participating in weight category sports. Surprisingly, our group has conducted the only study that has reported on this subject. We have recently shown that a 30-day KD does not adversely influence explosive and strength performance in a group of elite gymnasts when compared to a conventional ad libitum diet (17).

It is important to emphasize that competitive athletes have higher protein needs due to their rigorous physical activity. This was evident in the KD given in the study, which supplied roughly 2.8g protein kg-1 d-1 (17).

This is a key point: performance would probably suffer from an inadequate protein intake. The well-known "muscle-sparing effect," which takes place after a few days of ketosis, allowed the athletes to maintain their muscle mass and reduce their body fat even with this amount of protein (38).

During the initial stages of fasting, the breakdown of muscle tissue into amino acid precursors, or gluconeogenesis, provides the central nervous system (CNS) with glucose for energy. It is obvious that this is simply a short-term solution because neither long-term survival nor good performance are compatible with muscular atrophy. In order to circumvent this, increased production of KB occurs, offering an alternate energy source derived from fat that does not harm muscle tissue(38).

It is important to reiterate what has already been said: the pathways that lead to greater body fat utilization have certain characteristics with those that indicate a lack of development in muscle mass, but they typically do not signify either poor muscle performance or muscle loss. Lean body mass is often retained during a ketotic state because muscle protein catabolism is slowed but not stopped by the utilization of KB and FFA for energy. Although the exact mechanisms underlying this technique are unknown, it's possible that the previously noted "sparing effect" of using FFA as an energy source plays a part. Furthermore, leucine in particular has a well-known influence on protein synthesis through the mTOR signaling pathway (65), and this relative increase in amino acid absorption in the diet has been suggested as a critical component in the maintenance of lean body mass during KD.

Studies on people, however, have not yielded definitive results about this effect; alternatively, the ubiquitin-proteasome pathway's regulatory components may have been suppressed. In terms of "on-the-field" findings, Rhyu and Cho (66) have shown lately that in taekwondo athletes, three weeks of KD enhanced aerobic ability and fatigue resistance. Additionally, our data indicate that a 30-d KD does not reduce gymnasts' power output; hence, power athletes may find KD helpful in meeting weight categories without sacrificing their power output. Alternatively, if an athlete's goal is to gain muscle mass, a prolonged KD may interfere with some pathways of muscle growth, which could be detrimental.

## KD and Endurance Training

The available evidence on the application of the KD in sedentary/untrained people has yielded inconsistent findings, with some publications indicating a decline in physical performance (67) and others indicating an improvement (68). For instance, Phinney et al. (69) reported that during sustained activity at a level of 60% VO2max, mildly obese untrained persons may maintain this even with nearly no carbohydrate in the diet (G10 g d-1) over the course of six weeks.

Additionally, there was a noteworthy and unexpected increase in treadmill length time (from 168 to 259 minutes) compared with baseline after a mean weight loss of 7.1 kg (69). White and Colleagues (67) found that a KD (5% energy from carbohydrates) increased the participants' perception of fatigue during a 9-minute walk; however, the rate of perceived exertion was the only one that was significantly higher; neither the average heart rate nor the percentage of HRmax, which measures exercise intensity, changed. Other performance indicators, such as VO2max and blood lactate levels, were not examined.

Several recent studies, on the other hand, showed that, as compared to a high-carb diet, 8 weeks of KD improved fat oxidation in obese people and had no negative effects on maximal or submaximal indices of aerobic exercise performance or muscle strength (70). Additionally, it was noted that a KD can somewhat enhance cognitive function in terms of processing speed (71). According to the authors, there is no negative impact on one's capacity to execute resistance or endurance activities from a relatively long-term low-carb diet. Nonetheless, there are some differences between inactive participants and endurance athletes, and relatively few researches have examined the impact of KD in the former group. The first was conducted by Phinney et al. (1), who examined how long-term ketosis affected endurance athletes' abilities. They found that endurance riders' aerobic performance was unaffected in any way by consuming a ketogenic diet for four weeks. In off-road cyclists following a KD, a fairly recent study by Zajac and colleagues (18) showed a considerable improvement in the lactate threshold and rise in VO2max.

Even though the maximal workload and the workload at the lactate threshold were both significantly reduced on the KD, the authors explained their findings by pointing to increased fat oxidation, reductions in body mass and fat mass, and/or enhanced sympathetic activation as the reasons for the greater oxygen uptake required to obtain the same energy yield as on a mixed diet. (38)

Despite the inconsistent findings shown in these researches, a number of variables could account for the discrepancies:

a) The requirement of roughly 7 days for complete adaptation to physiological ketosis. According to Phinney (72), studies demonstrating a detrimental effect of a KD on performance were conducted for less than two weeks (67), which is insufficient time to observe the consequences of complete keto-adaptation. Because it takes 7 days to adapt, any results would only be noticeable for a few days; as a result, a 2-week treatment would be mediocre at best. Consequently, even though a recent study by Sawyer and colleagues (73) found that power output was not adversely affected in 31 trained individuals after just 7 days of a KD (5.4% carbohydrate, 35.1% protein, and 53.6% fat), athletes should programmed a KD for weight loss at least 2 weeks prior to competition; Consequently, even though a recent study by Sawyer and colleagues (73) found that power output was not adversely affected in 31 trained individuals after just 7 days of a KD (5.4% carbohydrate, 35.1% protein, and 53.6% fat), athletes should programmed a KD for weight loss at least 2 weeks prior to competition;

b) Whether or not electrolyte supplements were administered during a KD, tissue function and nitrogen balance require salt and potassium supply (72);

c) The quantity of protein consumed during a KD, as gluconeogenesis increases the requirement for protein; hence, an athlete's muscle mass may suffer from a low protein intake. (38)

## Perspectives for the future, real-world uses, and cautions

A growing body of research has been done on KD in recent years, but there aren't many studies on the topic of KD and athletic performance. In contrast, news and social media are rife with anecdotal accounts about sportsmen using KD. One of the key ideas to emphasize is that certain end goals are necessary to classify a nutritional approach as a KD:

1. Less than 5% of a KD's daily energy must come from carbohydrates, or less than 20grams of carbohydrates per day.
2. The daily requirement for protein in athletes should be between 1.2 and 1.7g kg-1 body weight (1,69,72) (up to 2.5g kg-1 body weight) in order to maintain lean body mass (17). This quantity is required to provide the bare minimum for gluconeogenesis and the replacement of bodily proteins.
3. According to Davis and Phinney (74), subjects who consumed 1.1 g of protein kg-1 of body weight during a 3-month period during a KD showed a significant reduction in VO2max compared with subjects given 1.5 g kg-1 body weight. This suggests that a lower protein intake may have an adverse effect on performance. Conversely, an overabundance of protein (92.5 g kg-1 body weight or greater than 25–30% of daily energy expenditure) may impede the process of ketogenesis. (38)
4. As mentioned before, fats are essential to achieving the daily energy requirement; hence, athletesmay or may not be given unlimited fat. (38)
5. An appropriate mineral intake is another crucial component. When the Inuit people live along the coast, they typically eat meat soups cooked in a brackish (mildly salted) water broth. They customarily added caribou blood, a strong source of salt, to their soup during mountain hunting expeditions. These conventional methods imply that potassium and sodium may be crucial during KD. Phinney et al. showed that supplementing with 3–5 g d-1 of sodium and 2–3 g d-1 of total potassium allowed their participants to maintain neutral nitrogen balance and circulatory reserve, which allowed for vasodilatation during submaximal exercise. (38)
6. The subjects must comply, and the diet plan must be examined by a qualified dietitian or expert nutritionist to ensure that the KD is being followed and to prevent KD-like treatments. (38)
7. To confirm that people are in ketosis, blood analysis should be done; blood exams utilizing a technology that uses capillary blood are preferred over urine investigations because, frequently, the absence of KB in the urine does not necessarily indicate that a subject is not in ketosis. (38)

There are a few factors to consider when organizing a KD:

I. It is generally known that during the initial days of KD, muscle glycogen and water play a major role in weight reduction. Approximately 3 grams of water are stored for every gram of glycogen. The contribution of fat steadily rises over the course of the days, and after 5 to 7 days, a notable increase in fat oxygenation should be predicted. (38)

II. Given the information at hand, it is plausible to assume that athletes will lose between 1.2 and 1.6kg of body weight (approximately 70 to 73kg in lean people) over the course of three to four weeks of KD. (38)

III. There shouldn't be any drop-in power output if the keto-adaptation time is followed and energy balance is kept (17).

## Conclusion

By reducing body mass and body fat in obese people and by enhancing fat oxidation in athletic populations, a KD may help improve body composition.

When it comes to BM and body fat loss, KD has no greater benefit than non-KD for athletes and obese people in an isoenergetic setting. FFM changes appear to be as great, if not higher, in sedentary obese persons as in those following an LFD.

Nonetheless, there are certain worries about the FFM decline in people after KD, particularly in athletes who have trained with resistance. Furthermore, compared to resistance-trained individuals, athletes undergoing ET exhibit a higher efficiency in the FFM-preserving effects of KD. Future carefully monitored studies on isoenergetic and iso-protein should involve individuals with a range of ages and training backgrounds (e.g. novice, trained or elite).
To support dieticians in creating appropriate dietary regimens for athletes and to validate the effects of KD on strength/power athletes, further data from well-controlled, randomized, controlled studies is still required.

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