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Impact of Nutritional Methods On Physical Performance Parameters

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Abstract

Introduction:

Contemporary nutritional strategies in sports play a crucial role, and it can be argued that, in a certain sense, they are paramount. This research aims to focus on three dietary approaches commonly utilized in various sports disciplines. The high-carbohydrate diet is particularly influential in endurance sports, owing to its properties that enhance muscle performance and efficiency. The core principle of this diet is the provision of large amounts of carbohydrates, providing the basic source of energy, which allows maintaining the level of glycogen in the muscles and liver.

In contrast to high-carbohydrate diets, high-protein and ketogenic diets have gained increasing popularity. The high-protein diet is especially recommended for strength and endurance athletes due to its ability to support anabolic processes and facilitate the repair of micro-muscular damage. On the other hand, the ketogenic diet, characterized by elevated fat intake, induces metabolic adaptations such as ketosis, wherein the body shifts from carbohydrate to fat.

Aim of study:

The aim of this study is to summarize the available knowledge about how diets influence sports indicators such as strength, endurance and ability to regenerate. The metabolism, mechanisms and different methods of diets were described and summarized.

Material and methods:

The literature available in PubMed, and the Google Scholar database was reviewed using the following keywords: „Ketogenic diet", „High carbohydrate diet", „High protein diet", „Diets in sport"

Keywords: Ketogenic diet, High carbohydrate diet, High protein diet, Diet in sports

High-carbohydrate diet

A high-carbohydrate diet is one of the most commonly employed nutritional strategies in endurance sports. It is becoming increasingly evident that maintaining adequate glycogen reserves in muscles does not require the use of restrictive dietary or training solutions [1]. Optimal glycogen stores typically delay fatigue and extend exercise duration [4]. The main premise of a high-carbohydrate diet is the inclusion of foods with low and moderate glycemic indices in the diet [3]. Carbohydrates account for 50 to 70% of the daily energy intake included in every meal [5]. The benefits of a high-carbohydrate diet are particularly noticeable in endurance athletes [5,3]. Research shows that both long-distance runners and cyclists achieve good results using this diet [1,4].

Mechanism of action and metabolism

Carbohydrates can be stored as glycogen, which serves a crucial role as an energy reserve. In the liver, glycogen functions as a reserve, and the key regulatory factor for its deposition is glucose. Glucose inhibits glycogenolysis and promotes glycogen synthesis through specific mechanisms. Glycogenesis is the chemical process of synthesizing glycogen from glucose [7]. This process primarily occurs in the liver. Glycogen, through glycolysis undergoes the process of transamination to alanine, which serves as a substrate for gluconeogenesis in the liver [8]. The glucose-1-phosphate released in this process is necessary for muscle activity by being converted into glucose-6-phosphate, which is incorporated in the process of glycolysis, where the product is ATP [6].

Benefits of a High-Carbohydrate Diet

A study conducted in the 1960s in Stockholm by Bergstrom demonstrated a relationship between muscle glycogen depletion and increased fatigue during endurance exercise [5]. A high-carbohydrate diet offers numerous benefits, especially for endurance athletes [3]. Positive effects of a high-carbohydrate diet include: higher energy levels and endurance, faster muscle recovery, improved performance during exercise, and enhanced capacity for intense training [3,4]. Each of these benefits are based on the principle that carbohydrates are the primary source of energy for muscles during intense physical activity. A high-carbohydrate diet allows for greater glycogen storage in muscles, which is critical for maintaining training intensity [1,3,5]. In a study with a group of male cyclists who consumed an isoenergetic diet (approximately 4000 kcal/day) for 3 days before the experiment, athletes followed various diets with different carbohydrate contents: low-carbohydrate (LowCHO), moderate carbohydrate (ModCHO), and high-carbohydrate, consisting of approximately 4000 kcal with a macronutrient distribution of 70% fat, 20% carbohydrates, and 10% protein. The clinical trial results showed that the high-carbohydrate diet enabled the cyclists to effectively utilize glycogen stores during the exercises, which had a direct impact on "gross efficiency" during the trial. Participants in the high-carbohydrate diet group achieved better performance, faster recovery, and enhanced endurance. The test results indicated that high carbohydrate intake over the 3 days prior to the exercise assessment increased the efficiency of the trained cyclists by approximately 4% compared to the moderate carbohydrate intake condition [1]. Carbohydrates (CHO) are a crucial energy source for the body, particularly during physical exertion of moderate intensity, when their metabolism is most active. For this reason, endurance athletes are often advised to follow a high-carbohydrate diet. Such a strategy can support training performance and improve overall physical endurance [3]. Another study analyzed the effects of different dietary regimens on the performance of young runners (ages 13–18) during a 10,000-meter race. The study involved nineteen boys who followed three types of diets for 48 hours: a high-carbohydrate diet (70% CHO), a normal diet (56% CHO), and a low-carbohydrate diet (25% CHO). Following the dietary period, participants completed a test run. The results showed that participants on the high-carbohydrate diet achieved a final sprint speed of 14.4 ± 2.2 km/h, surpassing the speed of 13.3 ± 2.4 km/h in the low-carbohydrate group ($p < 0.05$). In the high-carbohydrate group, the rate of carbohydrate oxidation was 1.05 ± 0.38 $g \cdot min^{-1}$, significantly higher than in the low-carbohydrate group (0.63 ± 0.36 $g \cdot min^{-1}$). The average completion time for the race was 50.0 ± 7.0 minutes in the high-carbohydrate group, representing a significant improvement compared to the time of 51.9 ± 8.3 minutes in the low-carbohydrate group ($p < 0.05$) [4].

High-Protein Diet

A high-protein diet is characterized by the consumption of protein in quantities higher than conventional dietary recommendations, typically ranging from 1.4g to 2g of protein per kilogram of body weight. Protein, one of the key macronutrients, performs a variety of essential functions within the human body [9]. It is particularly crucial for individuals engaging in physical activity, as it serves as the building block for muscle contractile elements, such as actin and myosin. Intense exercise causes muscle cell damage, and an adequate supply of protein is necessary to support the repair and recovery of muscle fibers [10]. The appropriate protein intake depends on factors such as the type and duration of physical activity, the individual's training level and body composition [9].

Animal vs Plant Protein

Protein, as a vital macronutrient, is essential for human nutrition, regulating metabolic pathways, satiety, and immune system activity. Proteins can be analyzed in terms of their qualitative profiles and classified into two groups based on their amino acid composition: high-quality and low-quality proteins. Commonly, these are referred to as animal and plant proteins, respectively. To ensure adequate protein intake, two key processes need to be considered: protein digestion and the absorption of essential amino acids (digestibility), as well as the redistribution of these absorbed amino acids for structural functions (bioavailability) [11]. Plant-based proteins, such as those from soy, peas, or quinoa, typically have an incomplete amino acid profile compared to animal-based proteins [12]. A 2021 study found no significant difference in training adaptations between sources of protein in untrained young men consuming adequate amounts of protein [13]. However, a meta-analysis indicated that animal proteins have a more favorable impact on lean body mass compared to plant proteins, particularly in younger adults [14]. Better athletic outcomes were observed in healthy individuals consuming plant protein, compared to those with initially very low protein intake. However, no significant improvements in endurance or muscle strength were noted when comparing plant protein to other protein sources, with plant proteins showing fewer positive results for certain outcomes [15].

High protein diet and sport

A study from 1997 demonstrated that protein intake immediately post-exercise may have a more anabolic effect than intake at other times. The study involved six untrained, healthy men who were intravenously administered a balanced amino acid mixture before and after resistance training to assess the effects of exercise on muscle protein kinetics caused by hyperaminoacidemia. The results showed a 30-100% greater increase in amino acid transport after resistance exercise compared to rest, indicating that exercise enhances blood flow, which in turn increases muscle protein synthesis. Thus, consuming an amino acid mixture post-exercise stimulates greater muscle protein synthesis [16].

Based on a systematic review and meta-analysis, the effect of increased daily protein intake on lean body mass (LBM), muscle strength, and physical performance was evaluated. The analysis involved lean, healthy adults who had their daily protein intake increased. The study concluded that increasing protein intake resulted in small additional gains in LBM and an improvement in lower body strength in adults who engaged in resistance exercise [17]. In novice individuals, protein supplementation is unlikely to impact lean body mass or muscle strength in the initial weeks of resistance training. However, as the training period extends, with increased frequency and exercise volume, protein supplementation may support muscle hypertrophy and strength gains in both untrained and trained individuals. There is also evidence suggesting that protein intake may accelerate improvements in both aerobic and anaerobic power [18].

A study showed that higher protein intake, especially after intense endurance exercise, could inhibit plasma protein synthesis related to myofibrillar damage, helping to reduce micro-injuries and speeding up recovery. This leads to a decrease in muscle soreness after training, facilitating faster recovery [19]. Additional protein supplementation significantly enhanced changes in muscle strength and size during prolonged resistance exercise training in adults with a healthy metabolic profile. Increased age decreased, while a higher training level enhanced the effectiveness of protein supplementation during resistance exercise. Protein intake above 1.62g/kg/day did not result in further gains in lean body mass following resistance exercise training [20].

The ketogenic diet, metabolism

The ketogenic diet primarily focuses on drastically reducing carbohydrate intake, while allowing for varying amounts of protein and fat. In its traditional form, the ketogenic diet typically consists of one gram of protein per kilogram of body weights and around 10–15 grams of carbohydrates per day, with the remaining calories derived from fat. The main goal of the diet is to induce a state of ketosis, where the body shifts from using carbohydrates as its primary fuel source to burning fat. This metabolic shift is believed to promote weight loss and may offer additional health benefits, such as lowering blood sugar levels and improving lipid profiles. Under normal conditions, the body predominantly uses carbohydrates as its main energy source, with insulin playing a key role in facilitating the uptake and storage of energy from glucose. However, when carbohydrate intake is limited, insulin secretion decreases. Initially, the body taps into glycogen reserves as a quick source of energy, but these stores are typically depleted within three to four days. At this point, stored fat becomes the primary fuel source. The breakdown of fat into free fatty acids provides the necessary components for ketone production in the liver. While ketone production is commonly associated with periods of starvation or extended physical exertion, it also occurs when following a very low-carbohydrate diet. It is important to note that in physiological ketosis, blood pH remains normal, unlike in pathological ketosis, where a decrease in blood pH can occur [21].

The ketogenic diet is a nutritional approach that promotes the production of ketone bodies (such as β-hydroxybutyrate, acetoacetate, and acetone) in the body, resulting in a state known as ketosis [22]. While ketosis can also be induced through other means, such as fasting or following a very low-calorie diet (which doesn't necessarily emphasize fats), it is important to note that these conditions do not constitute nutritional ketosis [23].

Mechanism of action

Glucose and fatty acids are metabolized into acetyl coenzyme A (acetyl-CoA), which is a byproduct of the partial breakdown of free fatty acids (FFAs) in the liver. Acetyl-CoA then enters the citric acid cycle (also known as the tricarboxylic acid cycle) by combining with oxaloacetate, which is derived from pyruvate. However, on a ketogenic diet (KD), where carbohydrate intake is extremely low, glycolysis is significantly reduced, leading to a lack of available oxaloacetate to combine with acetyl-CoA produced from fatty acid metabolism. As a result, acetyl-CoA is diverted toward ketogenesis, leading to an increase in ketone body production [24]. The primary ketone bodies synthesized in the body are β-hydroxybutyrate (βOHB), acetoacetate, and acetone. These ketones can cross the blood-brain barrier, providing an alternative energy source for the brain. While the heart, muscles, and renal cortex readily utilize ketones, the brain typically uses them only during extended periods of fasting. Erythrocytes (red blood cells) do not use ketones because they lack mitochondria, and the liver itself cannot use ketones due to the absence of the enzyme thiophorase [25]. Ketone bodies are considered a highly efficient energy source, as they generate more adenosine triphosphate (ATP) than glucose or fatty acids. This increased ATP production occurs by reducing the mitochondrial nicotinamide adenine dinucleotide (NAD) couple and oxidizing the coenzyme Q couple. For example, 100 grams of acetoacetate can produce 9.4 kg of ATP, while 100 grams of 3-hydroxybutyrate yields 10.5 kg of ATP. In comparison, 100 grams of glucose only generates 8.7 kg of ATP. This enhanced efficiency enables the body to sustain energy production even during periods of calorie restriction [26]. The ketogenic diet induces a state resembling starvation, which consequently leads to the process of autophagy and increased resistance to stress. This diet affects IGF-1/MTOR, which reduces the possibility of gaining muscle mass despite adequate caloric intake [27].

Impact of ketogenic diet on sports

Many athletes focus on achieving and maintaining an ideal body weight and composition for optimal performance in their respective sports. Athletes may aim to lose weight to enhance performance, improve their physical appearance, or compete in weight-class sports. This often leads to efforts to reduce body fat while preserving muscle mass, sometimes resulting in dietary practices that could have negative health consequences. The ketogenic diet (KD) has been utilized by athletes as a strategy for weight loss without negatively impacting performance, particularly in strength-based activities [28].

An important study in endurance runners showed that the KD increased peak fat oxidation [29]. This has been attributed to the enhanced capacity for fat oxidation. In another study, cycling performance during exhaustive exercise was improved through nutritional ketosis [30]. While this finding may have some limitations in human trials, future well-designed in vivo or in vitro experiments may further validate this result. Additionally, a study conducted over 762 days found that KD increased muscle mitochondrial volume [31]. Other research demonstrated that a 12-week KD combined with daily treadmill exercise resulted in increased gene expression related to fatty acid oxidation, compared to a control diet combined with exercise. In the KD groups, there was a decrease in the expression of genes associated with ketolysis, while the expression of genes involved in ketogenesis was elevated. These findings suggest that both the ketogenic diet and its combination with exercise have distinct effects on the regulation of energy substrate selection at the genetic level in energy-demanding organs such as the heart and skeletal muscles [32].

Anaerobic exercise, characterized by high intensity and short duration (typically less than two minutes), relies primarily on the phosphagen and lactic acid systems, both of which are heavily dependent on skeletal muscle glycogen. During anaerobic exercise, high contractile forces can cause muscle damage. In addition to replenishing carbohydrates during recovery, adequate protein intake is crucial to support muscle repair and rebuilding through protein synthesis. The low-carbohydrate (LC) and ketogenic diets typically provide enough protein (~15% of daily calories) to avoid amino acid deficiencies. However, due to the reduced carbohydrate intake, there is an increased reliance on amino acids for gluconeogenesis, and glycogen restoration may be impaired, which could negatively impact anaerobic performance. Several studies have explored the effects of LC/KDs on anaerobic performance, focusing on power or strength parameters across various populations, such as endurance athletes [33], CrossFit participants [34], gymnasts [35], and powerlifters [36]. These studies, which ranged from six to twelve weeks, included normal training regimens typical for each population. In general, the consumption of an LC/KD did not produce significant changes in strength or power compared to control groups [37]. These findings suggest that the LC/KD is not an effective strategy for increasing anaerobic performance in trained individuals or athletes, and it may even interfere with the expected gains in lean body mass from anaerobic training [37].

During prolonged moderate-intensity endurance exercise (50% to 70% VO2max), individuals following a high-fat diet exhibit a lower respiratory exchange ratio (RER) and lactate levels, but higher heart rate (HR) and VO2 compared to those on a mixed or high-carbohydrate diet [26]. A significantly reduced RER during submaximal exercise after following a ketogenic diet suggests an increased reliance on fat metabolism. The ketogenic diet in the current study also led to lower plasma lactate concentrations, both at rest and during moderate-intensity exercise, with the most notable reduction observed in the final 15 minutes of the maximal-effort phase of the exercise protocol [29, 38].

In conclusion, the ketogenic diet offers promising advantages for endurance athletes by optimizing fat metabolism and reducing lactate production, potentially improving exercise capacity during prolonged activities. [32]. However, for athletes involved in anaerobic sports, the diet may not be as beneficial and could impair performance due to limited glycogen availability [33]. Therefore, the ketogenic diet may be more suitable for athletes whose sports rely heavily on aerobic endurance rather than high-intensity anaerobic efforts [37]. Further research, particularly long-term studies, is needed to fully understand the impacts of the ketogenic diet on various aspects of athletic performance and recovery.

Conclusions

This research analyzes three primary nutritional strategies employed by athletes: the high-carbohydrate, high-protein, and ketogenic diets. Each of these diets possesses unique characteristics and exerts distinct effects on the body. The high-carbohydrate diet is particularly recommended for endurance athletes, such as long-distance runners or cyclists. By increasing glycogen stores in muscle tissue, it enables longer and more intense training sessions, enhancing endurance and accelerating recovery.

In contrast, a high-protein diet is crucial for individuals aiming to increase muscle mass and expedite recovery after intense strength training. Protein is the fundamental building block of muscle tissue, and adequate intake is essential for repairing the micro-damage caused by physical exertion.

The ketogenic diet, on the other hand, is a more restrictive dietary approach that may offer benefits in terms of weight reduction and metabolic health improvement. It may also enhance aerobic performance; however, it could potentially impair performance in anaerobic sports.

The overall conclusion is that there is no universal diet that is ideal for all athletes. The choice of an appropriate diet depends on individual training goals, the type of sport, taste preferences, and health status. Therefore, before making any significant dietary changes, it is advisable to consult a nutritionist. Each of the discussed diets has its strengths and can be effective when appropriately tailored to the athlete's needs.

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