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Literature Review

Keto Diet in Athletic Population

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Abstract

During exercise with progressively increasing intensity, it is a fact that the body of each individual, for the production of energy, initially uses carbohydrates, then, to a lesser extent, fats and, finally, to a minimal extent, the amino acids of proteins. The importance of carbohydrates in a diet aimed at athletic performance has been a given since the 1960s. From the 1980s onwards, however, alternative diets emerged, which are limited in carbohydrates and with increased fats, in percentages of approximately 60% fat and 25% carbohydrates (% of total calories consumed). That kind of diet is known as ketogenic diet. More specifically, during nutritional ketosis, ketone bodies replace glucose as the main form of energy for peripheral tissues such as the brain, the heart, etc. Whether nutritional ketosis benefits athletic performance is a controversial issue that is still being studied. This paper will attempt to examine the effects of a ketogenic diet on the athletic population. In particular, this paper examines primary data, derived from studies that analyze the effect of a ketogenic diet on athletes of sports that require physical strength and endurance. The results of our study demonstrate that most of the data recorded so far reveal that following a ketogenic diet does not improve athletic performance. In addition, a ketogenic diet is not considered to be ideal when it comes to increasing the muscle mass of athletes. Furthermore, the vast majority of the studies suggest that following a ketogenic diet is ideal for the reduction of body weight. However, research is still required in order to acquire a more comprehensive understanding of ketosis and how it affects the health and performance of the athletic population.

Keywords: *Ketogenic diet, Athletic Population, Low-carbohydrate ketogenic diet (LCKD), Literature review*

1. Introduction

The ketogenic diet is basically a low-carb, high-fat, moderate-protein diet. Its purpose is to put the body in a state of "physiological ketosis". (Paoli et al, 2015) Low carbohydrate intake combined with high fat intake results in the liver producing ketones, substances that result from fat metabolism for energy production (Neal et al., 2008). In essence, in the ketogenic diet the main source of energy for the body is fat instead of carbohydrates. Since the brain does not use glucose, i.e., carbohydrates, as "fuel", the body's requirements for muscle proteins are reduced to carry out the metabolism of carbohydrates and thus the rate of muscle catabolism is reduced (Lin et al., 2020). Reduced muscle catabolism also reduces the amount of ammonia reaching the liver. Simply put, this whole process has the effect of reducing protein losses in order to maintain the body's lean muscle mass. The ketogenic diet has been widely and successfully used to treat children with drug-resistant epilepsy since the 1920s. Even after so many years, according to research, the results show that by applying the ketogenic diet the epileptic episodes decreased to a fairly large extent (Neal et al., 2008). At the same time, it can alter the primary metabolism of brain energy from glucose to ketones, which involves multiple mechanisms of neuroprotection, antioxidant and anti-inflammatory effects, and is possibly an intervention to modify neurological disorders. However, a ketogenic diet can bring some side effects to the person who applies it, especially during the first period. The most common symptoms that can occur are usually not serious but can last for days to weeks. Such symptoms are headache, fatigue, hunger and nausea, irritability, poor sleep quality, reduced physical performance, lower blood sugar, indigestion, bad breath, muscle cramps in the legs, constipation and/or increased heart rate (Paoli, 2014). If these unpleasant symptoms subside, there are some negative side effects of long-term use of a ketogenic diet that might be permanent, including an increased risk of kidney stones and osteoporosis, increased levels of uric acid in the blood (a risk factor for gout).

2. Purpose of the study

The present study aims to investigate the effect of the keto diet on athletes of various sports. Specifically, the effect of the keto diet on the physical condition, body composition and strength power of the athletes will be studied. In addition, the effect of said diet on athletes' metabolism and weight loss will be studied.

3. Methodology

The methodology followed by the present study is that of the bibliographic review. Specifically, twelve studies from the available international literature related to the issue will be analyzed. Google Scholar and Microsoft Academic search engines were used to search for studies, with key words: athletic performance, keto diet. Inclusion criteria included: systematic reviews and primary research studies, publication period between 2010-2022, English language.

4. Results - Ketogenic diet and athletes

4.1 Impact of ketogenic diet on physical condition, body composition and strength power of athletes

Whether nutritional ketosis benefits athletic performance is a controversial issue that is still being studied. This is exactly what the study of McSwiney et al. (2019) investigates. The study of McSwiney et al. (2019) demonstrated that 28 days of ketogenic diet was a sufficient duration of retooling of muscle mitochondria to maintain endurance capacity at moderate intensity. One of the arguments put forward for endurance athletes following ketosis is that they will find it easier to complete moderate intensity exercise, as, theoretically, there is an abundance of free fatty acids, ketone bodies and liver glycogen, and increased glucose from precursors derived from fat and protein (gluconeogenesis). Despite achieving nutritional ketosis and increased lipid oxidation, endurance capacity remained limited, glycogen was reduced by 45% and there was no improvement in performance. In terms of strength training at both moderate and high levels, despite only 50 grams of carbohydrates, there was no reduction. Athletes in ketosis saw a slight decrease in their body weight. Of course, one difference between the groups that received carbohydrates and those that tried the examined diet, is the intake of proteins, where in both groups it was much higher in the group of ketosis. Perhaps this played a positive role in the maintenance of strength as well as the reduction in body weight observed. Regarding maximal strength close to 1RM, McSwiney et al. (2019) did not observe a clear difference. There was no increase but no decrease in maximum force. Similar results were seen in high-intensity exercise lasting less than 30 seconds. In conclusion, McSwiney et al. (2019) did not find any noticeable improvement in performance, but there was, in some cases, a reduction in body weight. In addition, another important finding is the effect of the ketogenic diet on vegetarian athletes. In particular, the study of Mujika (2019) examined a number of elite marathon runners, triathletes and professional cyclists, who tried this diet for 8 months. They reported their worst performance in an Ironman half distance test (21 weeks in ketosis), second worst Ironman performance (at 24 weeks), and, eventually, they failed to finish the Ironman (32 weeks) by stopping the diet from then on. Given the need to study the effects of ketogenic diets (KD) in well-trained resistance athletes, the study of Vargas, et al. (2018) aimed at determining whether a hyper-caloric KD diet would lead to greater gains in lean mass and fat loss during a hypertrophic training period in resistance-trained men. Twenty-four healthy men with more than 2 years of continuous hypertrophy training experience participated in this randomized controlled trial. Since few studies have evaluated the effect of a ketogenic diet, combined with resistance training, on visceral fat percentages, the study of Vargas, et al. (2018) coincides with the current literature showing a significant reduction in visceral fat in the KD group. This reduction could have a health benefit due to the inverse association with cardiometabolic diseases, where visceral fat is the main cause. In general, the KD group achieved a positive change in body condition due to the reduction in body weight. Thus, their fat mass decreased, but in terms of lean muscle mass, a non-ketogenic or conventional carb nutritional approach, combined with a caloric surplus and higher protein intake, seems to be the best choice to achieve muscle hypertrophy and development (Vargas, et al., 2018). The KD group showed almost no improvement in lean muscle mass, in contrast to the athletes on a classic sports diet, high in carbohydrates and higher in protein. Thus, Vargas et al. (2018) conclude that a low-carb nutritional approach, such as ketogenic, may not be the most suitable for maximizing muscle mass. However, it is an ideal choice for weight loss, especially in obese people and people with cardiovascular diseases. The study of Wilson et al. (2020) examined the impact of an isocaloric and isonitrogenous ketogenic diet (KD) versus a conventional western diet (WD) on changes in body composition, blood lipids, performance, and hormonal profiles in resistance-trained athletes. According to the study, lean body mass (LBM) increased in both KD and WD groups at week 10. However, only the KD group showed an increase in LBM between weeks 10-11. Finally, fat mass decreased in both the KD group and WD groups. Strength and power increased to the same extent in the WD and KD conditions from weeks 1-11. In addition, no changes in any serum lipid measures occurred from weeks 1-10 (Wilson et al., 2020). When comparing the KD diet to the WD diet from pre to post, total testosterone increased considerably from Weeks 0 to 11, whereas insulin did not alter. The KD can be used in combination with resistance training to cause favorable changes in body composition, performance and hormonal profiles in resistance-trained males.

4.2 Impact of a ketogenic diet on the metabolism of athletes

The study of Volek et al. (2015) compares two groups of elite high-endurance athletes. One group of athletes follows a diet with very low carbohydrates (LC), while the other one follows a diet with a high percentage of carbohydrates (HC). The athletes were carefully divided according to criteria of age, physical characteristics, and their athletic performance, and the test of the athletes was completed in two days. Compared to the baseline, pre-exercise measurement, muscle glycogen decreased by 62% immediately post-exercise and 38% at 2 hours post-exercise in the HC group. The LC group showed similar numbers as muscle glycogen decreased by 66% immediately post-exercise and 34% 2 hours later (Volek et al., 2015). There were no significant differences in pre-exercise or post-exercise glycogen concentrations between groups. On the contrary, there was a significant difference in duration. The amount of glycogen synthesized at 2 hours of exercise in LC athletes was much higher than that of HC athletes. In conclusion, compared to high-endurance athletes consuming a HC diet, long-term keto-adaptation results in extremely high rates of fat oxidation, while muscle glycogen utilization and repair during and after 3 hours of aerobic exercise are similar. However, as regards athletic performance, ketogenic diet did not seem to have any benefits (Volek et al., 2015). The objective of the study of Durkalec-Michalski et al. (2019) was to determine the effects of a four-week ketogenic diet (KD) on the utilization of fat and carbohydrates (CHO) during an incremental cycling test (ICT) in athletes who had completed a CrossFit training program. During the ICT (while consuming the standard diet and after the KD), oxygen absorption and carbon dioxide exhalation were measured, and CHO and fat utilization as well as energy expenditure were computed. The KD resulted in an increase in fat oxidation in males, which was very obvious at exercise intensities up to 80% of VO2max. At fat consumption levels up to 65 percent VO2max, males but not females had a rise in the area under the curve (AUC). In conclusion, male CrossFit athletes appear to be more susceptible than female athletes to changes in macronutrient utilization (in favor of fat utilization) during submaximal intensity exercise when following a ketogenic diet (Durkalec-Michalski et al., 2019). Wentz et al. (2010) showed that heart muscle activates a metabolic response that restricts ketone body use using mice models in ketotic nutritional settings (24 hours of fasting and a very low carbohydrate ketogenic meal). When 13C-labeled ketone bodies are administered in vivo or ex vivo, NMR profiling shows that maintenance on a ketogenic diet produces a 25% reduction in cardiac 13C enrichment of glutamate, indicating lower procession of ketones through oxidative metabolism. As a result, unmetabolized substrate concentrations are greater in the hearts of mice on a ketogenic diet when they are subjected to a ketone challenge than they are in the hearts of chow-fed controls (Wentz et al., 2010). Additionally, decreased ketone body oxidation is associated with ketone bodies' inability to prevent fatty acid oxidation. These findings suggest that systems that limit ketolytic ability are activated in ketotic nutritional situations, regulating how ketone bodies are used when a person is in a ketotic state. Although a change in blood acid-base ratio occurs with a short (up to 3 days) exposure to significant changes in macronutrient intake, the effects of prolonged (> 1 week) interventions in elite athletes have not been determined. Using a non-randomized, parallel design, Carr et al. (2018) examined the effect of adaptations to 21 days of a ketogenic diet (low-carbohydrate, high-fat - LCHF) or intermittent carb, i.e., different amounts of carbohydrate per day (PCHO) on pre- and post-exercise blood pH and lactate concentration [La-] compared to a high-carbohydrate diet (HCHO). At baseline, there were no differences in blood pH between HCHO, PCHO and LCHF. As expected, there was a significant decrease in blood pH after exercise for all groups. After three weeks, there were no significant differences between groups before exercise for HCHO and PCHO, compared to LCHF, respectively (Carr et al., 2018). However, at the 2-min post-exercise time point, pH was significantly lower for PCHO compared to LCHF, with no significant difference between HCHO and LCHF. Similarly, at 4 min and 6 min postexercise, pH was significantly lower for PCHO compared to the 2 other groups, again with no significant difference between HCHO and LCHF. As regards the concentration of lactic acid, there were no significant differences in the blood between the groups at the start of exercise and for any time point during but also up to 6 minutes after. The results suggest that continuous manipulation of macronutrient intake is unlikely to affect blood acid-base (pH) status in elite athletes (Carr et al., 2018). It is a system that is regulated through the interaction of the blood and tissues, as well as the respiratory and renal systems.

4.3 Impact of ketogenic diet regarding weight loss

The study of Greene et al. (2018) aimed at determining whether a low-carbohydrate ketogenic diet (LCKD) could be used as a weight reduction strategy for athletes competing in the weight class sports of powerlifting and Olympic weightlifting. In particular, lean mass and body mass were considerably reduced during the LCKD period compared to the normal diet (UD) phase. Lifting performances did not alter between dietary stages and did not reflect lean mass reductions. Between dietary phases, there were no additional variations in primary or secondary outcome variables. Lifting performances were equivalent to their UD for weight class athletes who consumed an ad libitum LCKD. Therefore, according to Greene et al. (2018), a LCKD should be used by coaches and players to meet specific weight loss objectives for weight class sports (Greene et al., 2018). The aim of Rhyu and Cho's (2014) study was to examine how Taekwondo athletes' performance-related physical fitness and inflammatory cytokines was affected by weight loss using a 3-week ketogenic diet. There was no difference between the KD and NKD groups in weight, percentage of body fat, BMI and fat free mass.

The KD group, as opposed to the NKD group, completed the 2,000-meter sprint in less time after losing weight, felt less fatigued as determined by the Wingate test, and had less tumor necrosis factor- rise. According to the findings of the study of Rhyu and Cho (2014), the KD diet can benefit weight category athletes like Taekwondo athletes by enhancing their aerobic and fatigue resistance capacities as well as by having a positive impact on their inflammatory response.

According to Chang et al (2017) the significant metabolic functions due to LCKD diets seem to improve performance. More specifically, high fat oxidation and high glycogen enhance performance in endurance sports. This may also reduce the effect of limited performance due to prolonged periods of high intensity training. However, Chang et al (2017) argue that high levels of ammonia and free fatty acids produced, might contribute to central nervous system fatigue. They also mention that all adaptations occur after few months of LCKD diets. Similarly, Kiens and Astrup (2015) argue that low and very low in carbohydrates diets increase the fat oxidation rate, however this doesn’t seem to improve endurance in athletes.

5. Conclusions

Food is very important in human life, not only because humans get all the nutrients their body needs to stay alive, but also because it pleases them with its taste, smell, appearance and color. Of course, their choices are also guided by other factors, e.g. economic, religious factors, availability of food depending on the season, but mainly from their way of life. The most basic principle is to meet the body's energy and nutrient requirements (vitamins, minerals, proteins, fatty acids, etc.). For a diet to be nutritionally adequate it must contain all the nutrients necessary for life support, physical activity and growth. These requirements are different for each person, because they depend on their individual characteristics (height, weight, age, etc.) but also on their lifestyle (daily activities, sports, etc.). Thus, each person's diet plan is personal. An athlete is fed not only to support good health and wellness, but also to benefit in terms of athletic performance. A ketogenic diet is a quite special choice especially when it is followed for a long time. Choosing this type of diet does not usually have a negative effect on health, given that you follow it based on the right foods and taking the right supplements. Research shows positive benefits in serious diseases, such as cancer or other neurological diseases. The length of time one follows the diet and the foods one chooses are such important factors that they can reverse the potential benefits of this dietary choice. When we refer to sports performance, the data is perhaps more specific. In particular, research shows that there is no better diet than the classic protocol of a high carbohydrate and protein diet, when it comes to increasing strength and muscle mass. In addition, as Vargas et al. (2018) report, a low-carb nutritional approach, such as ketogenic, may not be the most suitable for maximizing muscle mass. In endurance athletes or short distance sprinters it may not have a negative impact on most athletes, but research shows less improvement than the control group (Volek et al., 2015). Furthermore, studies show that there is no noticeable improvement in the performance of athletes who follow a ketogenic diet (Volek et al., 2015; McSwiney et al., 2019). Nevertheless, Wilson et al. (2020) report that KD can be used in combination with resistance training to cause favorable changes in body composition, performance and hormonal profiles in resistance-trained athletes (males). Moreover, research shows that a ketogenic diet can affect the metabolism of athletes, since, for instance, the continuous manipulation of macronutrient intake is unlikely to affect blood acid-base (pH) status in elite athletes (Carr et al., 2018). Finally, according to a number of studies, when the goal is to lose body weight and fat, choosing a ketogenic diet for a period of 4 to 8 weeks for most athletes will be quite a beneficial choice (Rhyu & Cho, 2014; Greene et al., 2018; McSwiney et al., 2019). However, research is still needed to get a global view on ketosis and its effect on health and performance of athletes. Nevertheless, it remains at the discretion of every athlete to try this diet and decide if it suits them.

Conflict of Interest

The author declares no conflict of interest.

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