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Recommended Athletic Consumption of Carbohydrates: A Review

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ABSTRACT

This paper explores the relationship between carbohydrate consumption and its effect on athletic performance with deep insight into the timing, amount, diets, and temperature. Evaluating data from different research papers found that carbohydrates can be crucial in sustaining and increasing athletic performance. However, most studies emphasize the importance of personalized carbohydrate consumption and caution against common diet trends on social media. One common trend is that consuming carbohydrates 2-4 hours before physical exercise can improve glycogen storage and performance. Recommendations on carbohydrate consumption may vary depending on intensity and duration, while overconsumption may hinder athletic performance.

Keywords - *Carbohydrates, Exercise, Athletes, Diets, Performance*

1. INTRODUCTION

With the advancements in the sports world and athletic performance, nutrition can be a game changer to achieve peak performance. Among various options of nutrients and diets, carbohydrates often stand out as one of the most important parts of an athlete's diet. This is because carbohydrates play a significant role in sustaining energy levels during exercise. When carbohydrates are consumed they are broken down into a monosaccharide the glucose inside the small intestine where it is then transported through the bloodstream. Generally, it is advised that carbohydrates make up 55% to 70% of an athlete's energy source. This would mean around 10 to 12 grams of carbohydrates per kilogram of body mass per day. (Podlogar and Wallis 5)

However due to the beauty standard, athletes are exposed to daily on social media platforms, they tend to limit their calorie intake to keep a low body fat percentage. By following diets such as Keto, crash diets and binge eating, recommended carbohydrate intake is often not met. This in particular affects young female athletes, who are vulnerable to societal pressure to keep up with certain body standards. However, this athlete's performance often suffers and recovery time is much longer.

Whilst just including carbohydrates in your diet is important, many factors can play a role in how effective the results are. For example, the timing of carbohydrates during physical exercise can be crucial in determining the effectiveness of improving overall performance. Although carbohydrates will provide energy and replenish glycogen levels whether taken before, during or after exercise they should be tailored to meet athlete's demands of both training and competition. Further, the metabolic pathways involved in carbohydrate usage can differ depending on the intensity, duration and type of exercise. (Wallis 4) Aerobic degradation of glycogen provides you with slow-release energy which can be used during endurance activities, while anaerobic degradation provides rapid releases of energy used during high-intensity sports.

It is also key for athletes to understand the industry norms and their common misconceptions to fuel their race, more sustainably. Often an athlete's diet and conception of things is influenced by what they view on social media and what they are exposed to daily. However, sometimes products such as sports energy drinks and supplements advertised for athletes often result in the opposite. This is often caused by big corporations driven by profiting from athletes by receiving money rather than supporting the athlete. For example, the NFL has been accused of downplaying the risk of concussions for years to protect the league's profitability. They then concealed research that linked football to brain damage.

This research paper explores the pivotal role in the understanding of the relationship between carbohydrate consumption and athletic performance. Critical timing as well as the amount and type of carbohydrate will also be discussed. Providing insight that can inform and improve nutritional practices for athletes looking to achieve peak performance.

2. EFFECTS OF TIMING OF CARBOHYDRATES

The timing of carbohydrate intake before, during and after exercise is crucial for optimal performance.

Studies have found that strategic carbohydrate consumption hours before exercise can help maximize muscle, and liver glycogen levels and prevent athletes from feeling hungry.

Consuming carbohydrates during this time has been found to increase endogenous glycogen stores, which are in charge of regulating glucose production. (Kerksick et al. 2) It is often recommended for people to consume carbohydrates 2 to 4 hours before exercise. With the recommendation that "athletes should take 1–4 g/kg of CHO per body weight" (Mata et al. #). Other studies have also found that "low pre-exercise glycogen levels result in early fatigue, reduced training intensity, depleted muscle glycogen, impaired muscle contraction, glycogenolysis, and protein degradation." Therefore athletes need to consume carbohydrates well before training or competition. However, an "excessive consumption of carbohydrates may adversely affect performance" (Mata et al. #). A study found that the response to carbohydrate ingestion directly before (<60min) exercise can result in a negative hypoglycemia response. It is said that consumption of carbohydrates during this period can result in decreased performance, which can be explained by the fact that the rise in insulin because of the carbohydrate ingestion with "up-regulation of GLUT-4 transporters from the initiated exercise stimulus", can result in a decrease rather than increase in blood glucose level during activity. Comparing these two studies, we can tell that consuming carbohydrates before exercise had more positive effects since the study was conducted in 2018 whilst the other one was conducted in 2017, so through the improvement in nutrition in digestion both endurance and short-distance athletes can now profit from carbohydrate intake during exercise. However, it must be always recommended to consume carbohydrates a few hours before exercise rather than last minute. Also often should be paired with "1 g/kg of CHO in a pre-event meal with a protein source" (Mata et al. #).

Consuming carbohydrates during exercise is usually only recommended for endurance athletes and long training sessions. During this, you should "aim to consume 30 to 60 grams of carbohydrates per hour of exercise" (Hassapidou #), through convenient sources such as energy gels or sports drinks. However, according to a study by the Journal of Sports Science, carbohydrate intake should be continued during all durations of exercise stating that during "sustained high-intensity sports lasting less than 1 h, small amounts of carbohydrate, including even mouth-rinsing, enhance performance via central nervous system effects."

Table 1

Exercise duration	The recommended amount of carbohydrate	Type of carbohydrate
< 45 minutes	None	None
45–75 minutes	Very small amounts (mouth rinse)	Any
1–2.5 hours	30 – 60 g/h	Any
> 2.5 hours	Up to 90 g/h	Multiple transportable carbohydrates (glucose or maltodextrin + fructose)

(Jeukendrup 27)

Table 1 shows the carbohydrate intake recommendation depending on the duration of exercise. Generally, carbohydrate intake recommendations increase with increasing duration. There is also a change in the type of carbohydrate recommendation with the increase in duration. Figure 1 also supports the first study that carbohydrate intake should be prevented during short periods of exercise, with only very small amounts being consumed above 45 minutes. Exercise above 2.5 hours should consume 'Multiple transportable carbohydrates', which consists of using different carbohydrates such as glucose, fructose, and maltodextrin, to maximize their utilization and absorption during exercise. Although these guidelines can be applied to most athletes it is important to keep in mind that "when the absolute exercise intensity is low carbohydrate oxidation rates are also low" (Jeukendrup #) so recommendations should be adjusted downward.

Weather and outdoor temperature can play a big role in the amount of carbohydrates an athlete should consume during exercise.

Whilst it can be recommended that athletes should consume carbohydrates before and during exercise to give athletes an advantage, studies have found that most importantly carbohydrates should be consumed after exercise. Consuming large amounts of fast-digesting carbohydrates after exercise can help rebuild muscle tissues. After prolonged exercise carbohydrate consumption can help promote a favorable hormonal environment. Thus manipulating the glycogen stores (endogenous) and CHO intake (exogenous), after training or competition can increase exercise performance.

According to a study by Pubmed Central, athletes should intake different amounts of high-glycemic index CHO (1/g/kg/h) two to four hours after the training session.

The combination of protein and carbohydrate can result in significantly improved performance and much less muscle damage.

In conclusion, the timing of carbohydrate intake before, during, and after exercise is crucial for optimal performance in training and competition. Most studies agree that consuming carbohydrates a few hours before training can help maximize muscle and liver glycogen levels, whilst consuming carbohydrates during exercise can increase endogenous glycogen stores. Most studies agree that consuming carbohydrates during exercise should be done by all athletes exercising more than 45 minutes and can be adjusted depending on absolute exertion intensity. However, excessive carbohydrate consumption can negatively impact performance. After exercise, large amounts of fast-digesting carbohydrates can help rebuild muscle tissues and promote a favourable hormonal environment. The timing of carbohydrates can vary between athletes and can be adjusted to fit training requirements.

3. EFFECT OF QUANTITY AND QUALITY OF CARBOHYDRATES ON ATHLETES

Sports nutrition researchers have said that athletes often forget the basic feeding principles in the quest to find the next "big thing". Although protein and fat can provide the necessary energy to perform physical activity, carbohydrate is the substrate most efficiently metabolized by the body and "the only macronutrient that can be broken down rapidly enough to provide energy during periods of high-intensity exercise when fast-twitch muscle fibres are primarily relied upon." (Kanter 36)

There are different types of carbohydrates athletes can consume. Both simple and complex carbohydrates are broken down into glucose, providing an equal source of energy.

The two major types:

'Simple' CHO foods cause large and rapid release of blood glucose levels on ingestion (a rapid rise followed by a rapid and often greater fall). These carbohydrates usually have a sweet taste but are not a sustainable source of energy.

'Complex' CHO foods provide complete digestion as well as absorption but at a much slower rate compared to simple CHO foods. The result of this is a much flatter and more sustained blood glucose response. Although this is the more sustainable option for athletes it usually does not have a sweet taste.

The question often arises which of these carbohydrates is better for athletes and if they can have negative effects. Often athletes are told to completely avoid **simple** CHO foods, however, studies have found that consuming these carbohydrates before exercise can provide a short energy burst, which is particularly important during competition as well as immediately after exercise.

Thus during training sessions that are shorter than one hour, athletes should look to consume 30-60 g/per hour of simple carbohydrate foods.

A few hours (3-4) before physical exercise athletes should aim to consume"6-10 grams of Complex CHO foods per kg of body weight per day, depending on training load".

4. THE HEALTH ASPECT OF DIETS THAT ATHLETES FOLLOW

The dietary practices athletes follow play a major role in shaping body composition and influencing physical performance and overall health. And most often completely ignored is how one's dietary practices can affect long-term mental health. An ideal athlete's diet consists of: "45 to 65% from carbohydrates, 15 to 25% from protein and 20 to 35% from fat". However, most athletes do not follow these guidelines as they are different from non-athletes. This results in athletes following different diets such as crash diets, Ketogenic diets, Intermittent Fasting and substances for optimal performance. Whilst these diets often have the benefits of weight loss the body is encouraged to use fats instead (good for endurance athletes).

The benefits often blind athletes from the fact that these diets can also have negative effects on their health. Many athletes, in particular endurance athletes, partake in the Ketogenic Diet, to lose weight and boost performance. During this diet athletes drastically reduce their carbohydrate intake, to about 20-50 grams a day which roughly translates to less than 10% of total calorie intake. Following this, there would be an increase in fat consumption (70-80 per cent) and moderate consumption of protein (20%). The diet works in the way that when carbohydrate consumption is limited to less than 50 grams daily, insulin secretion is decreased significantly, putting the body into a catabolic state. The result is " two prominent metabolic processes: gluconeogenesis and ketogenesis" (Masood et al. #). Although the diet is accepted in the media, the ketogenic diet remains controversial in medical and athletic communities. This is because although the diet may be beneficial in some aspects, it still poses risks of side effects, fatigue, reduced training response, dizziness, vomiting, decreased performance and well-being.

According to a study following the ketogenic diet showed to have positive effects on athletes in short duration, and vigorous-intensity tests. However, another study by the American College of Cardiology completely disagrees with this saying that following a keto diet can pose limitations in high-intensity/anaerobic-metabolic states of exercise. Additionally, following a ketogenic diet can lead to nutrient deficiencies, particularly in vitamins and minerals found in carbohydrate-rich foods. Following this, the keto diet also poses the risk of increased acidity which results in kidney stones and poor bone health.

Oppositely a high carbohydrate diet focuses on consuming around 60% of total dietary energy. This can have many benefits since it's the body's preferred source of energy and has lots of nutritional benefits. Especially for endurance athletes following a "high carbohydrate diet can increase muscle glycogen stores" (Fogelholm et al. 5), which are essential for prolonged endurance activities and thus delaying the onset of fatigue. Although endurance athletes have more benefits from this diet, sprinters may also be able to profit from the energy source as it can "provide the fuel needed for explosive power and speed" ((Slater et al. 84) by breaking down carbohydrates into glucose into glycogen which is then broken down in the muscle, liver.

However, if carbohydrate intake exceeds 70% of total calories over longer periods it may lead to chronically elevated levels of insulin which may potentially lead to insulin resistance. "This can result in impaired glucose uptake into the muscles, consequently may result in negative performances in high-intensity activities that rely heavily on carbohydrate metabolism" (Tischer 23). High carbohydrate diets can be associated with both the development and prevention of type 2 diabetes. This is because it depends on the type of carbohydrate one is choosing. Simple carbohydrates like glucose and fructose can be quickly broken down into sugar causing a rapid rise in blood sugar levels which may be helpful in competitions where a quick burst of energy can give you an advantage. Therefore

consuming simple carbohydrates in large quantities can lead to heart disease, diabetes and obesity.

On the other hand eating Complex carbohydrates (three or more sugars linked together, known as oligosaccharides and polysaccharides) like beans, and oats can take "longer to digest which means they have less of an immediate impact on blood sugar, causing it to rise more slowly" (Harvard T.H. Chan). This can help maintain insulin levels and even reduce the risk of diabetes two.

There are many ideal diets out there for athletes, with set timings and food groups. However, this is often hard for athletes to do as they may not have the time or resources to follow such diets. Such as in weight-sensitive sports or ballet weight and body shape are often closely looked at, often resulting in anorexia as well as other eating disorders.

Anorexia is frequently caused by the pressure placed on athletes to maintain a lean physique by greatly restricting calorie intake. Carbohydrate malabsorption is often observed in anorexia patients. A mortality rate of 5.9% has been reported (Sullivan. 980)), although death may not be the case for most people, athletes will be more prone to injury and tend to have shorter sports careers. Further athletes suffering from anorexia tend to suffer from "dehydration and electrolyte imbalances" (Ghoch et al. 2), as well as a "decreased VO2 max, which is the maximum amount of oxygen the body can use during exercise", thus significantly decreasing endurance based sports performance (Ghoch et al. 35). All of these factors can cause psychological strain, leading to issues with concentration, mood stability and continuously affect physical performance negatively draining motivation as well as increasing stress levels.

5. AEROBIC DEGRADATION AND ANAEROBIC DEGRADATION

The body can utilize carbohydrates through two major metabolic pathways: Aerobic and anaerobic degradation. By athletes understanding how these two pathways work, they can majorly improve their athletic performance.

Aerobic degradation involves the breakdown of carbohydrates in the presence of oxygen. Therefore a slower process than anaerobic degradation but produces much larger quantities of ATP. Aerobic degradation takes place in the mitochondria, producing around "36-38 mmol of ATP per glucose molecule" ((Hawley et al. 71). This is particularly utilized by endurance athletes such as cyclists, marathon runners or distance swimmers.

Anaerobic degradation is the breakdown of carbohydrates without the presence of oxygen and happens very rapidly. Anaerobic degradation of glycogen is a slower process, it occurs in the "cytosol and relies on phosphocreatine kinase to generate ATP from phosphocreatine and ADP" (Williams and Rollo 8). Anaerobic degradation can produce between 2-3 mmol of ATP per glucose molecule, which is significantly less than what is produced by aerobic degradation. This process is most commonly used by weightlifters and sprinters who require short and very quick bursts of energy.

6. ENVIRONMENT TEMPERATURE, BAROMETRIC PRESSURE AND THE EFFECTS ON CARBOHYDRATE CONSUMPTION

Temperature and humidity can play a major role in carbohydrate metabolism and energy production. High temperatures can increase muscle glycogen utilization, resulting in elevated core temperatures which can "accelerate metabolic rates, leading to increased energy expenditure and reduced performance" (Hawley et al. #). Higher temperatures can degrade physical performance by increasing fatigue and greatly reducing endurance capabilities. A major reason for this is that high temperatures can cause heat storages in the body, and these heat storages "increase sweat rate, which may induce dehydration" (Horswill et al. 585). "Fluid ingestion is a strategy that minimizes dehydration and attenuates the rise in core temperature by maintaining plasma volume, which helps to sustain cardiac output and skin blood flow for heat dissipation" (Horswill et al. 24). To do so sports drinks contain carbohydrates such as Gatorade can be very useful.

According to some studies, temperature has more of an effect on endurance athletes, especially when rehydration is limited, stating that it may cause the total blood volume to be compromised. This will further limit the amount of carbohydrates and oxygen transported to your muscles. However, the study also stated that the temperature can only have a major degrading effect on performance if the core temperature is also elevated. Through "acclimatization for 10 to 14 days" (Terrados and Maughan #) you can decrease the effects.

However when exercising in cold temperatures, factors such as "the capability of the cardiovascular system to deliver oxygen to the working muscle, the ability of the metabolism to produce a sufficient amount of energy mostly from stored substrates, the adequate function of the neuromuscular system, and maintained psychological capabilities" (Gatterer et al. 10) is decreased by cold exposure. Whilst exercising in cold conditions, glycogen stores are accelerated which uses up a lot more carbohydrates. This means that during this time the body switches from using the body's energy metabolism towards increased carbohydrate utilization. This is done because the body needs to shiver.

Thus when exercising in colder environments athletes should look to consistently consume carbohydrates, this means carbohydrate-rich snacks before, during and after exercise. A guideline for athletes is that they may choose to consume "30-60 grams of carbohydrates per hour during extended training sessions in the cold." (Bailey 2). Because unlike for athletes in warmer climates, acclimatization will not work in the cold.

Barometric pressure can lead to improvement in the sprint by 0.3-0.7%, however in mid-distance and long distance they show dramatic impairments of 2-4% (above 1000 m). Although there is an "improvement in sprinting at high altitudes, athletes increase energy expenditure by 10 to 15 per cent." (Gatterer et al. 12).

Lastly "Cold exposure can lead to accelerated muscle and liver glycogen utilization. During shivering, carbohydrate metabolism can increase up to six times compared to resting levels" (Gatterer et al. 17). This shows that when exercising at high altitudes you should consume more carbohydrates.

Carbohydrates are an essential source of energy, for sustaining energy levels, increasing endurance and providing easier recovery. The timing of carbohydrate consumption can play a pivotal role in maximizing performance, whether before, during or after exercise. It is recommended to take in carbohydrates 2 to 4 hours before exercise, consuming 1–4 g/kg of CHO per body weight. This can help in glycogen replenishment and prevent early fatigue, whilst taking carbohydrates during exercise can help improve endurance. On the other hand, post-exercise carbohydrate consumption can aid recovery and muscle reparation. Additionally, the type and amount of

carbohydrate consumed can also play a crucial role. Simple CHO foods can provide quick energy bursts for short-term needs whilst complex CHO foods can support more sustained energy levels.

Athletes can learn to balance this more closely to aid their performance, and environmental conditions can further affect this. In hot environments, athletes should look to consume more carbohydrates and electrolytes to prevent fatigue. The paper further highlights the need to be cautious about diet trends that are influenced by social media and body standards. Extreme diets, such as ketogenic or crash diets, can negatively impact performance and health. Further showing that a variety of body types are capable of performing well. However, if carbohydrate consumption exceeds 70% of total calories it can lead to chronically elevated levels of insulin which may potentially lead to insulin resistance. As a result, ending in negative athletic performance. To conclude, athletes can greatly improve their athletic capabilities by watching the timing, quantity, and type of carbohydrates and catering to their individual needs.

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