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The New Carbohydrate Intake Recommendations

Asker Jeukendrup

School of Sport and Exercise Sciences, University of Birmingham, Birmingham, UK

Abstract

Carbohydrate intake during prolonged exercise has been shown to increase endurance capacity and improve performance. Until recently, the advice was to ingest 30–60 g of carbohydrate per hour. The upper limit was based on studies that demonstrated that intakes greater than 60–70 g/h would not result in greater exogenous carbohydrate oxidation rates. The lower limit was an estimated guess of the minimum amount of carbohydrate required for ergogenic effects. In addition, the advice was independent of the type, the duration or the intensity of the activity as well as the level of athlete. Since 2004, significant advances in the understanding of the effects of carbohydrate intake during exercise have made it possible to be much more prescriptive and individual with the advice. Studies revealed that oxidation rates can reach much higher values (up to 105 g/h) when multiple transportable carbohydrates are ingested (i.e. glucose:fructose). It has also been observed that carbohydrate ingested during shorter higher intensity exercise (1 h, 80%VO_{2max}) can improve performance, although mechanisms are distinctly different. These findings resulted in new recommendations that are dependent on the duration and intensity of exercise and not only specify the quantity of carbohydrate to be ingested but also the type.

Introduction

It has been known for some time that carbohydrate ingestion during exercise can increase exercise capacity and improve exercise performance [for reviews, see 1–4]. Although the exact mechanisms are still not completely understood, in general, two major mechanisms have been described and are either ‘metabolic’ or ‘central’ in origin.

The oldest and most established mechanisms relate to the effects of carbohydrate intake on metabolism. During exercise longer than 2 h, carbohydrate ingestion helps to maintain blood glucose concentrations and high rates of carbohydrate oxidation. This in turn, delays the onset of fatigue, extends time to exhaustion and can increase performance. The ergogenic effects of carbohydrate ingestion during exercise of high intensity (>75%VO_{2max}) and relatively short duration (~1 h) have a different origin and are not related to metabolism but reside in the central nervous system instead. Carbohydrate mouth rinses have been shown to result in performance improvements [5–9] suggesting that the beneficial effects of carbohydrate feeding during exercise are not confined to its conventional metabolic advantage but may also serve as a positive afferent signal capable of modifying motor output [10]. These effects are specific to carbohydrate and are independent of taste [11]. The receptors in the oral cavity have not yet been identified, and the exact role of various brain areas is not clearly understood. Further research is warranted to fully understand the separate taste transduction pathways for various carbohydrates and how these differ between mammalian species, particularly in humans. However, it has been convincingly demonstrated that carbohydrate is detected in oral cavity by yet unidentified receptors, and this can be linked to improvements in exercise performance [for review see 9]. New guidelines suggested here take these findings into account (fig. 1).

These results suggest that it is not necessary to ingest large amounts of carbohydrate during exercise lasting approximately 30 min to 1 h, and even a mouth rinse with a carbohydrate solution may be sufficient to get a performance benefit (fig. 1). In most conditions, the performance effects with the mouth rinse were similar to ingesting the drink, so there does not seem to be a disadvantage of taking the drink, although anecdotally athletes may complain of gastrointestinal distress when taking on board too much fluid. Of course, when the exercise is more prolonged (2 h or more), carbohydrate becomes a very important fuel, and it is essential to ingest carbohydrate. As will be discussed below, larger amounts of carbohydrate may be required for more prolonged exercise.

Different carbohydrates ingested during exercise may be utilized at different rates [2], but until a landmark publication in 2004 [12] it was believed that carbohydrate ingested during exercise could only be oxidized at a rate no higher than 1 g/min (60 g/h) independent of the type of carbohydrate. This is reflected in guidelines published by the American College of Sports Medicine which recommends that athletes should take between 30 and 60 g of carbohydrate during endurance exercise (>1 h) [13].

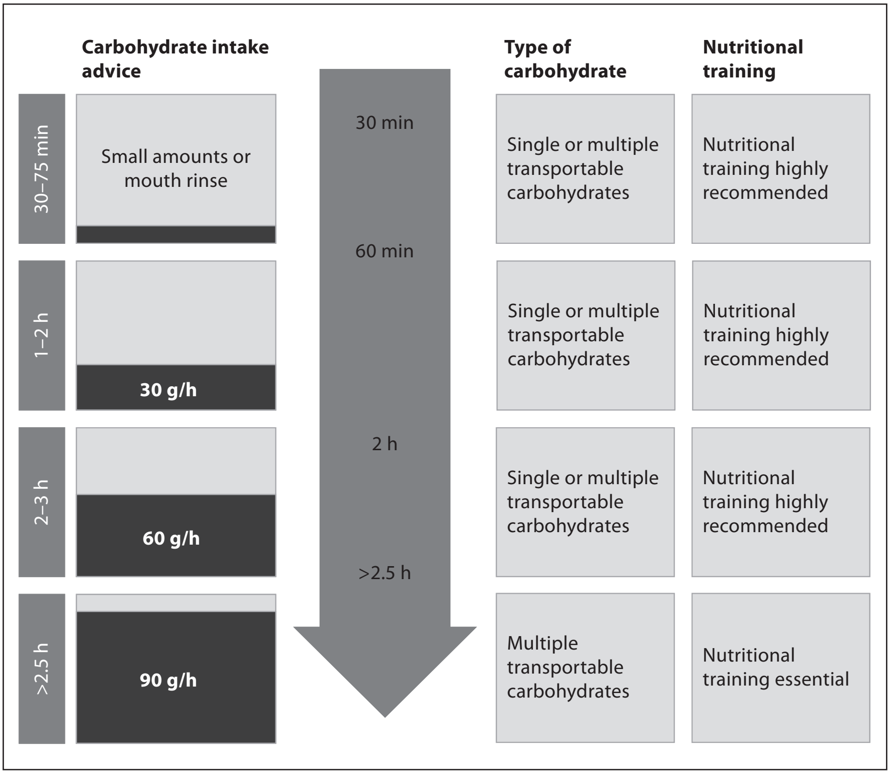

Fig. 1. Carbohydrate intake recommendations during exercise for exercise of different durations. These values are for high-level athletes and should be adjusted downwards for aspiring athletes.

Exogenous carbohydrate oxidation is most likely limited by the intestinal absorption of carbohydrates. It is believed that glucose uses a sodium-dependent transporter SGLT1 for absorption, which becomes saturated at a carbohydrate intake around 60 g/h. When glucose is ingested at this rate and another carbohydrate (fructose) that uses a different transporter is ingested simultaneously, oxidation rates that were well above 1 g/min (1.26 g/min) [12] can be observed. A series of studies followed in an attempt to work out the maximal rate of exogenous carbohydrate oxidation. In these studies, the rate of carbohydrate ingestion was varied and the types and combinations of carbohydrates differed. All studies confirmed that multiple transportable carbohydrates resulted in (up to 75%) higher oxidation rates than carbohydrates that use the SGLT1 transporter only [for reviews, see 1, 2]. Interestingly, such high oxidation rates could not only be achieved with carbohydrate ingested in a beverage but also as a gel [14] or a low-fat, low-protein, low-fiber energy bar [15].

Carbohydrate during Exercise and Performance: Dose Response

Very few well-controlled dose-response studies on carbohydrate ingestion during exercise and exercise performance have been published. Most of the older studies had serious methodological issues that made it difficult to establish a true dose response relationship between the amount of carbohydrate ingested and performance. Until recently, the conclusion seemed to be that you needed a minimum amount of carbohydrate (probably about 20 g/h based on one study), but it was assumed that there was no dose-response relationship [16].

In the last few years, evidence has been accumulating for a dose-response relationship between carbohydrate ingestion rates, exogenous carbohydrate oxidation rates and performance. In one recent carefully conducted study, endurance performance and fuel selection were measured during prolonged exercise while ingesting glucose (15, 30, and 60 g/h) [17]. Twelve subjects cycled for 2 h at 77%VO_{2peak} followed by a 20-km time trial. The results suggest a relationship between the dose of glucose ingested and improvements in endurance performance. The exogenous glucose oxidation increased with ingestion rate, and it is possible that an increase in exogenous carbohydrate oxidation is directly linked with, or responsible for, exercise performance [3, 4, 17, 18].

The superior effects of high intakes of multiple transportable carbohydrates seem to present themselves when the exercise duration is around 2.5 h or longer, and has not been demonstrated for shorter exercise bouts. Multiple transportable carbohydrates are essential to deliver these relatively large amounts of carbohydrate (>60 g/h). Multiple transportable carbohydrate ingestion does not result in increased exogenous carbohydrate oxidation or performance when ingested at rates below 60 g/h [19]. There are however no disadvantages to taking multiple transportable carbohydrates at rates below 60 g/h, and these carbohydrates are just as effective as a single source.

Training the Gut

Since the absorption of carbohydrate limits exogenous carbohydrate oxidation, and exogenous carbohydrate oxidation seems to be linked with exercise performance, an obvious potential strategy would be to increase the absorptive capacity of the gut. Anecdotal evidence in athletes would suggest that the gut is trainable and that individuals who regularly consume carbohydrate or have a high daily carbohydrate intake may also have an increased capacity to absorb it. Intestinal carbohydrate transporters can indeed be upregulated by exposing an animal to a high-carbohydrate diet [20]. To date, there is limited evidence in humans. A recent study by Cox et al. [21] investigated whether altering daily carbohydrate intake affects substrate oxidation and in particular exogenous carbohydrate oxidation. It was demonstrated that exogenous carbohydrate oxidation rates were higher after the high-carbohydrate diet (6.5 g/kg bodyweight per day; 1.5 g/kg bodyweight provided mainly as a carbohydrate supplement during training) for 28 days compared with a control diet (5 g/kg bodyweight per day). This study provided evidence that the gut is indeed adaptable, and this can be used as a practical method to increase exogenous carbohydrate oxidation. We recently suggested that this may be highly relevant to the endurance athlete, and may be a prerequisite for the first person to break the 2-hour marathon barrier [22].

Intermittent and Skill Sports

The vast majority of studies has been performed with endurance athletes performing continuous exercise. Most team sports have a highly intermittent nature with bursts of very high-intensity exercise followed by relatively low-intensity recovery periods. Besides this, performance in these sports is often dependent on other factors than maintenance of speed or power, and factors like agility, timing, motor skill, decision making, jumping, and sprinting may all play a role. Nevertheless, carbohydrate ingestion during exercise has also been shown to enhance endurance capacity in intermittent activities. A large number of studies have demonstrated that if carbohydrate is ingested during intermittent running, fatigue can be delayed and time to exhaustion can be increased [23–27].

More recently, studies have incorporated measurements of skill into their performance measurements. Currell et al. [28] developed a 90-min soccer simulation protocol that included measurements of skill, such as agility, dribbling, shooting and heading. The soccer players performed 90 min of intermittent exercise that mimicked their movement patterns during a game. During the 90 min, skill performance measurements were performed at regular intervals. Agility, dribbling and accuracy of shooting were all improved, but heading was not affected with carbohydrate ingestion. Other studies have found similar effects. Although typically a number of the skills measured in these studies were improved with carbohydrate feeding, the mechanisms behind these improvements are unknown and have not been studied in any detail.

It appears that carbohydrate intake during team sports and other sports with an element of skill has the potential to improve not only fatigue resistance but also the skill components of a sport, especially towards the end of a game. The practical challenge is often to find ways to ingest carbohydrate during a game within the rules of the sport.

Conclusions

There have been significant changes in the understanding of the role of carbohydrate during exercise in recent years, and this allows for more specific and more individualized advice with regard to carbohydrate ingestion during exercise. The new guidelines proposed take into account the duration (and intensity) of exercise, and advice is not restricted to the amount of carbohydrate, it also gives direction with respect to the type of carbohydrate. The recommendations presented here are derived mostly from studies with trained and well-trained athletes. Athletes who perform at absolute intensities that are lower will have lower carbohydrate oxidation rates and the amounts presented here should be adjusted accordingly. The recommended carbohydrate intake can be achieved by consuming drinks, gels, low-fat, low-protein and low-fiber solid foods (bars), and selection should be determined by personal preference. Athletes can adopt a mix and match strategy to achieve their carbohydrate intake goals. However, the carbohydrate intake should be balanced with a fluid intake plan, and it must be noted that solid foods and highly concentrated carbohydrate solutions have been shown to reduce fluid absorption. Although this can partly be prevented by using multiple transportable carbohydrates, this is something the athlete needs to consider when developing his/her nutrition strategy. Finally, it must be noted that most studies are based on findings in runners and cyclist, and more work is needed to establish the effects and underlying mechanisms of carbohydrate ingestion on skill components in intermittent team sports.

Disclosure Statement

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Questions and Answers

Question 1: Carbohydrate provision maximizes performance. If you use carbohydrate blends (glucose, maltodextrin, fructose), you can actually absorb more carbohydrate during exercise. What are the practical limits for carbohydrate intake during exercise?

Answer: If you use a mix of different carbohydrates, we call them multiple transportable carbohydrates, you can achieve very high absorption and oxidation rates, and that has been shown to result in better performance during prolonged exercise (>2.5 h). It is important to realize that this only happens if you ingest relatively large amounts of carbohydrates. If you consume less than 60 g of carbohydrates per hour, you do not see these effects. You only see it if you push the carbohydrate intake higher than 60 g of carbohydrate per hour. We typically recommend around 90 g/h during this type of activity. That is actually quite a lot of carbohydrate to take on board during exercise, especially if you are not used to it. If you are unaccustomed, you can get some stomach discomfort, maybe some intestinal cramps. So the challenge is to ingest relatively large amounts of carbohydrate without causing gastrointestinal distress. The only way to get around this is to get used to it and use this practice in training. If you are planning to use this practice during a race, do not use this practice during the race for the very first time. Always practice the nutrition strategy in a training situation, and do it about once a week so the body is used to handling these large amounts of carbohydrate.

Question 2: Glucose availability in the mouth seems to directly improve performance capacity. Under what conditions would a little carbohydrate already have a practical relevance towards improve performance?

Answer: In some situations you do not need to actually ingest the carbohydrates to get the effect, but this is very specific to short-duration events. Most of the studies have investigated something around 60 min of all-out exercise, so maybe you see the effects from 30 up to 75 min. But it has to be an all-out effort for that period of time. Then, you can get these performance effects even with a simple mouth rinse. So, you can chose to rinse your mouth with a carbohydrate drink or you can chose to drink little bits of carbohydrate, and that should help your performance.

Question 3: Does this work only with glucose, or does this work with other sweeteners?

Answer: It does not work with any sweetener because in studies we and others used the sweetener as the placebo, and the carbohydrate improves performance compared with that placebo. So, it is a very specific effect of the carbohydrate and not of the sweetness. We have also done these studies with carbohydrates that have no taste and you can still see the performance effect. In fact, there are also studies that show that if you give a carbohydrate that is not sweet, it activates certain areas of the brain. So it is definitely a carbohydrate effect and not a sweetness effect.

Question 4: What is your personal and practical recommendation for carbohydrate intake during exercise for athletes?

Answer: The answer is: it depends. It depends on the level of athlete you are, and it depends on the type of event that you are involved in. Generally, if you are a higher level athlete who works out at higher absolute intensities, you probably need a little bit more carbohydrate. The event duration also matters. So if the event is very short you need smaller amounts of carbohydrate than when the event is very long. When the event is 2.5 h or longer and you really want optimal performance, you probably have to push the carbohydrate intake to as high as 90 g of carbohydrate per hour, use carbohydrates that contain multiple transportable carbohydrates. If you are in an event that is between, say 2–3 h, then you can probably get away with 60 g/h. If it is shorter, then you can go to 30 g/h. So, it really depends on what event you are looking at and what level of athlete you are.

Question 5: Is there also a difference if you consume carbohydrates during exercise as a solid food or as a liquid supplement?

Answer: That is a good question. We have recently done those studies where we compared drinks versus gels versus bars, and it turns out that it does not really matter how the carbohydrates are delivered. Gels with water are almost exactly the same as a sports drink. If you give carbohydrate bars with water, it is almost the same as a sport drink as well. But I think it is important that the bars or solid foods that you choose are low in fat, low in fiber and low in protein because as soon as you increase the content of those ingredients, you will slow down the delivery of the carbohydrate.