A REVIEW

Carbohydrate Intake Guidelines During Exercise Evolution and Current Controversies

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ABSTRACT

Carbohydrate is one of the major fuels for providing energy during exercise. In endurance events of longer duration, the carbohydrate stores in muscles and liver starts depleting which can lead to early fatigue and adverse effects on performance. Therefore, after substantial researches, guidelines for carbohydrate intake have been formed. There are some disparities in these recommendations provided by different institutes. Inclusion of body mass in the recommendations is one major debatable issue. Besides, all guidelines considerably focus on carbohydrate intake based on intensity and duration of exercise. Where, in events lasting less than 1 hour, no carbohydrate intake or only mouth rinse is sufficient, for events longer than 2 hours, the type of carbohydrate consumed also play a crucial role. During practical implementation, carbohydrate intake should be individualized based on tolerance and preferences of the athlete.

KEYWORDS

Endurance Exercise, Carbohydrate, Recommendations, Glucose

INTRODUCTION

Carbohydrate (CHO) is one of the most important nutrients to enhance performance in endurance sports. Various sports nutrition research organizations have provided different recommendations for carbohydrate intake, on daily basis, and during exercise. The recommendations for daily intake, are quite a similar based on body mass, duration and intensity of exercise and universally accepted. In the last two decades, lot of research work have been performed to study the effect of carbohydrate supplementation during exercise and based on that new recommendations have been formed which comprise duration, intensity of exercise, type of carbohydrates and body mass. In contrast, to focus on carbohydrate intake according to body mass in daily intake recommendations, the guidelines formed by International Olympic Committee (IOC) for CHO intake during exercise excludes body mass. Rather, they are given in absolute amount based on duration and intensity of exercise. Only American College of Sports Medicine (ACSM) guidelines include body mass as a component for carbohydrate intake during exercise. This review explores the relevance of inclusion of body mass for determining the amount of carbohydrate to be consumed during exercise based on existing literature.

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Carbohydrate metabolism during endurance events

Carbohydrate and fat are two major fuel sources to provide energy during an endurance event. However, the total contribution of fats towards the energy is very small. About 700g of carbohydrate is required if it is the sole nutrient to be used as a fuel, which is higher than what is stored in liver and muscles (Maughan & Gleeson, 2012). According to Coggan and Chole (1991), blood glucose levels are equally important as muscle glycogen levels in contributing to energy production during several hours of strenuous exercise. Blood glucose levels can be maintained by liver or exogenous carbohydrate intake in prolonged exercises. Glycogenolysis and gluconeogenesis in liver is stimulated by moderate intensity exercise to provide constant glucose supply to muscles (Suh et al, 2007). Exogenous carbohydrate contributes towards increasing carbohydrate oxidation, leading to increased time to exhaustion during endurance events (Coyle et al, 1986). Carbohydrate delivery (>90g/hr) via blood stream and carbohydrate oxidation is enhanced when muscle glycogen stores are low and helps in enhancing performance (Stellingwerff & Cox, 2014). Fat and protein are not recommended to be consumed during exercise as they can serve as inhibitor of gastric emptying and thus can delay the delivery of nutrients and energy into blood stream (Brouns & Beckers, 1993). Thus, carbohydrate had been identified as best exogenous source to provide constant energy during prolonged events. However, excess intake of carbohydrate using concentrated carbohydrate solutions may lead to gastrointestinal distress (Rehrer et al, 1992). Therefore, it was necessary to form specific carbohydrate intake guidelines during exercise for optimal performance.

Carbohydrate intake guidelines

The major aspects of current carbohydrate intake guidelines are: total carbohydrate intake during a day; carbohydrate loading for competition; its intake during exercise; and post exercise recovery. The initial guidelines started with recommendations for total carbohydrate intake during a day and as the researches advanced specific recommendations for the other aspects were formed.

The carbohydrate intake guidelines in the early nineties were based on per cent of total energy intake. For an optimum diet in sports, carbohydrate was recommended to contribute 60-70% of total energy (Devlin & Williams, 1991). These recommendations were revised in the next decade as they were not related to muscle's absolute needs for fuel (Burke et al, 2004). Burke and colleagues (2004) explained that terms per cent carbohydrate of energy intake and carbohydrate gram per kg body mass cannot be used interchangeably and use of former term has various disadvantages in expressing carbohydrate needs for athletes. As athlete's needs are very much different form general population and they require carbohydrate to optimize muscle glycogen recovery, it's better to provide these needs based on body mass which is a rough indicator of size of muscle mass (Burke et al, 2004; Costill,1988; Rankin, 1995).

The revised guidelines in 2004 (Burke et al, 2004) were based on body mass, intensity and duration of exercise, for immediate and daily recovery. Nevertheless, it did not include the amount of carbohydrate intake during exercise or competition.

Carbohydrate intake during exercise

Coyle and Coggan in 1984 demonstrated that carbohydrate feeding during moderate intensity activity of >2 hours can delay the development of fatigue upto 15-30 minutes. Intake of 30-70g of carbohydrate per hour during prolonged exercises was proposed by Rankin (1995) to delay hypoglycemia, glycogen depletion, and fatigue. The current guidelines of carbohydrate intake during endurance exercise by ACSM and American Dietetic Association (ADA) (Rodriguez et al, 2009) are based on body weight and duration of exercise (Table 1). However, IOC's guidelines (Burke et al, 2011) have not included body mass as a component and focuses only on duration, intensity and type of carbohydrate (Table 1). The fundamental dissimilarities in recommendations of these two major sports nutrition research organizations for intake of carbohydrate during exercise has led to the debate weather body mass is a potential influencer of exogenous carbohydrate requirements, during endurance events.

Table-1: Current recommendations of carbohydrate intake during exercise

Organization	Recommended Intake	CHO Type
ACSM and ADA (Rodriguez et al, 2009)	Carbohydrate 0.7g/kg body weight per hour or 30-60g/hour	Multiple Transportable carbohydrate
IOC (Burke et al, 2011)	Carbohydrate not required for <30 minutes of exercise	--
	Mouth rinse with CHO solution for 30-75 minutes of exercise	Most forms of CHO
	Upto 30 gram per hour for 1-2 hours of exercise	Most forms of CHO
	Upto 60 gram per hour for 2-3 hours of exercise	Multiple Transportable carbohydrate
	Upto 90 gram per hour >2.5 hours of exercise	Multiple Transportable carbohydrate

Body mass and carbohydrate intake during exercise

The joint statement of AESM and ADA have recommended 0.7g/kg body mass/hour carbohydrate intake, during prolonged exercise, which they stated to be equivalent to 30-60g of carbohydrate per hour. The researches quoted in the position statement support the fact that 30-60g of carbohydrates can be beneficial; but, neither any of the studies translated these finding into per kg of body mass nor gave any physiological basis for the same. Besides, the position statement itself could not elucidate how they derived this conversion. There is lack of quality researches specifically focusing on the effect of body mass on exogenous carbohydrate oxidation. According to Jeukendrup (2010), body mass does not seem to have impact on exogenous carbohydrate oxidation.

Other factors affecting carbohydrate requirements

Two different theories have been explored for carbohydrate requirement for events upto 1 hour and longer than that. Carbohydrate mouth rinse have been identified as effective strategy to improve performance, for events upto one hour, as it leads to carbohydrate sensing of central nervous system, which further improves motor output (Carter et al, 2004).

While exercising, muscle glycogen is primary source of carbohydrate to muscles. As the muscle glycogen content decreases, liver maintains the blood glucose levels through glycogenolysis and gluconeogenesis and can readily provide carbohydrate to muscles (Suh et al, 2007). However, the exogenous carbohydrate consumed during exercise has to pass through gastro-intestinal barriers before appearing in the blood. Therefore, the researches in the recent years focused on mechanism lying behind gastric emptying, absorption of exogenous carbohydrate during exercise, liver glycogen synthesis, rather than its relation with body mass for exercises longer than one hour. Gastric emptying (Gisolfi, 2000), liver glycogen synthesis ((Jeukendrup et al, 2006) and muscle glucose uptake (Hawley et al, 1994) do not appear to affect the exogenous carbohydrate oxidation to a significant extend.

Intestinal absorption has been established as a major limiting factor of carbohydrate oxidation (Jeukendrup & Jentjens, 2000) in events longer than one hour, nullify the effect of body mass or muscles. Earlier, it was thought that exogenous CHO oxidation rates cannot exceed 1.0 to 1.1 g/min (Jeukendrup & Jentjens, 2000).

However, in recent years, it has been established that exogenous carbohydrate oxidation rates can reach upto 1.75 g/min, using multiple transportable carbohydrates as source. Different type of carbohydrates uses different transporters at intestinal membrane and thus prevents saturation of a particular transporter and enhances absorption into blood stream (Jeukendrup, 2007).

CONCLUSION

Improving intestinal absorption of exogenous carbohydrate is of great importance, as it will enhance carbohydrate oxidation rate. However, further researches are required to study the actual impact of body mass with supplementation of carbohydrate blends when exogenous carbohydrate oxidation is at its peak.

Key Message for Athletes and Coaches

The guidelines of IOC for carbohydrate intake during exercise are far more revised and evidence based then ACSM and ADA position statement. These guidelines can be followed; however, individual tolerance and preference should be considered, providing ample time for adaptation before applying them in a competition setting.

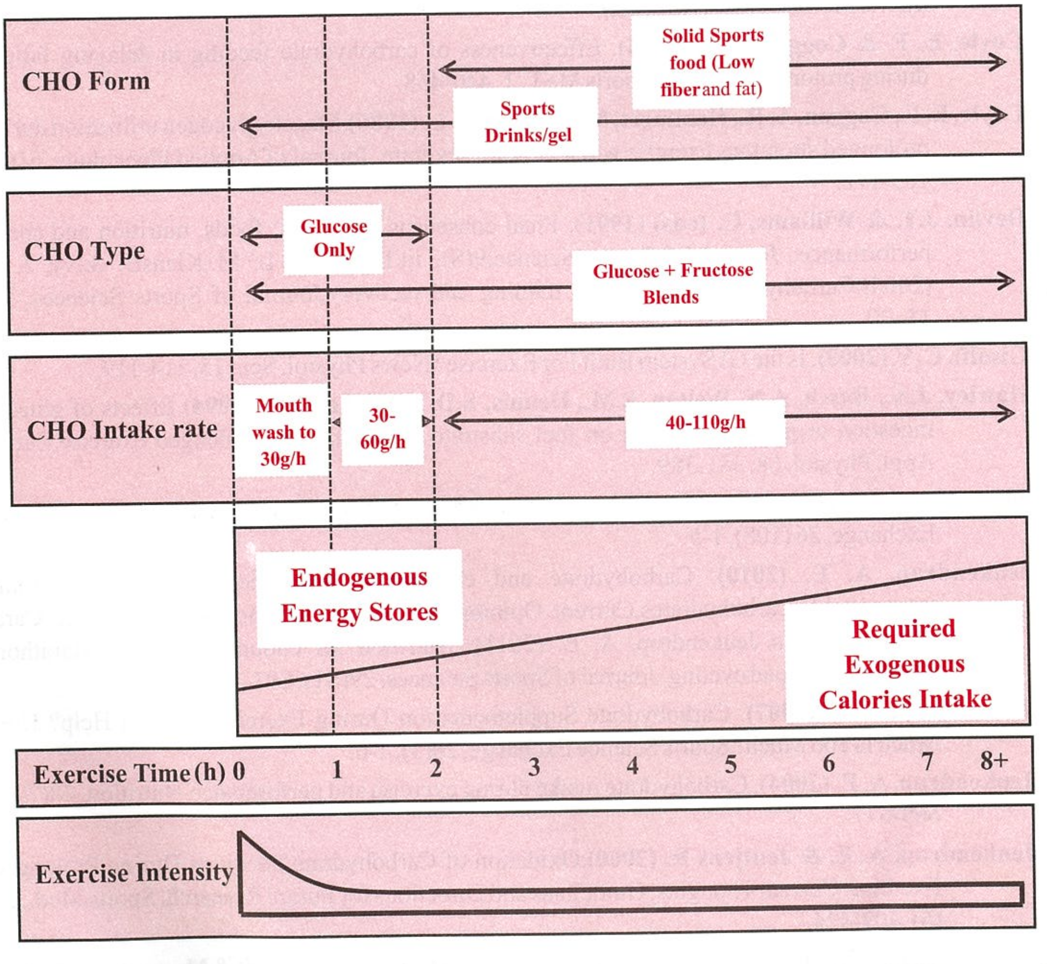

Fig.-1: Schematic overview of key recommendations for CHO intake rate, CHO type and form over varying exercise duration and intensities (Stellingwerff and Cox, 2014)

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