

# THE SCIENCE OF **CARBOHYDRATE**



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This document provides an overview of the scientific literature related to the carbohydrate needs of athletes, including why and when to eat carbohydrate, what type to consume and the appropriate amount.

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#### INTRODUCTION

Carbohydrate (CHO) is the primary fuel source for moderate and high-intensity exercise.<sup>2</sup> The stored form of CHO in the muscle and liver, called glycogen, supplies most of this fuel and can be manipulated by diet and training. The body has small amounts of CHO stored in the liver (~80 g, 320 kcal) and muscle tissue (300-500 g, 1200-2000 kcal). CHO intake throughout the day, and before and after training and competition, will help to ensure adequate glycogen stores. During training or competition of an hour or longer, CHO intake will help support this relatively limited fuel supply to help maintain performance.<sup>1,2,7,10</sup>

#### DAILY CARBOHYDRATE INTAKE

Due to the additional energy demands of training, CHO recommendations for athletes are higher than the general population. The recommendations are meant to support CHO availability for the muscle and central nervous system based on the demands of the sport.<sup>2,16</sup> Additionally, in order to adequately support the increased energy demands, the daily recommendations are based on body weight rather than given as a percentage of total calories. See Table 1 for the daily CHO recommendations for athletes competing in various sports.

Researchers have been investigating the benefits of training with lower carbohydrate availability to manipulate endurance training adaptations. However, evidence to date does not support this strategy.<sup>5</sup> A low-carb high-fat diet may impair the ability to train at high intensity levels and is unlikely to change aerobic capacity or exercise performance in endurance athletes.<sup>4</sup>

Type of Activity	Carbohydrate Targets
Low intensity or skill-based activities	3-5 g/kg of athlete's body weight/d
Moderate exercise program (eg, -1 h per day)	3-7 g/kg of athlete's body weight/d
Endurance program (eg, 1-3 h/d mod-high- intensity exercise)	6-10 g/kg of athlete's body weight/d
Extreme commitment (eg, >4-5 h/d mod-high- intensity exercise)	8-12 g/kg of athlete's body weight/d

Table 1: Daily carbohydrate recommendations for athletes<sup>2,6,16,17,18</sup>





#### **CARBOHYDRATE BEFORE TRAINING & COMPETITION**

**Timing and Amount**: In the 1-4 hours pre-exercise, the athlete should consume between 1-4 g of CHO/kg of body weight.<sup>216</sup> The choice of where within this range an athlete falls depends on a number of factors including the type of sport/event, goal of the athlete and any stomach issues. For example, a marathon runner preparing to complete a 20-mile training run will be on the high end of the range, whereas a football lineman preparing for a game may be on the lower end. It is important that the athlete try out various strategies with form, amount and timing to find what works best for him or her.

Within about one hour before exercise, the amount and type of CHO to consume is based on athlete preference and tolerance. Intake in this window begins to meet the "during" exercise needs for the athlete, and is particularly important if the athlete cannot or will not consume fuel during their training or competition.<sup>9</sup> Many athletes do well with about 25-30 g during this time, which is an appropriate amount when considering the during-exercise recommendations discussed below.



**Type**: Before exercise, athletes should choose carbohydrate-rich foods with minimal fiber, fat and protein. These nutrients can slow the digestion and absorption process, and if consumed close to the start of exercise, potentially cause gastrointestinal distress during exercise. All athletes should practice pre-exercise nutrition strategies to find the best timing and amount that will work for them during competition.

Duration	CHO Amount	СНО Туре
<30 minutes	Not needed	Not needed If chosen - rapidly oxidized CHO (e.g. glucose, sucrose, maltodextrin)
30-75 minutes	Small amounts including mouth rinse	Rapidly oxidized CHO (e.g. glucose, sucrose, maltodextrin)
1-2 hours	Up to 30 g/hr	Rapidly oxidized CHO (e.g. glucose, sucrose, maltodextrin)
2-3 hours	Up to 60 g/hr	Rapidly oxidized CHO (e.g. glucose, sucrose, maltodextrin)
>2.5 hours	Up to 90 g/hr	Multiple transportable CHO (2:1 glucose:fructose)

Table 2: During-exercise carbohydrate needs for endurance athletes<sup>2,10,13</sup>



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#### **CARBOHYDRATE DURING TRAINING & COMPETITION**

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**Timing and Amount**: The amount of CHO that can be absorbed through the intestines during exercise is limited; therefore, recommendations are independent of body weight.<sup>8</sup> Team sport athletes, when practicing or competing for an hour or longer, should consume 30-60 g of CHO per hour of exercise in order to support exercise performance.<sup>1,2,15</sup>

During competition, it may not be practical for athletes who participate in power sports, such as swimming, to consume CHO.<sup>17</sup> The focus on competition days should be pre-exercise CHO and post-exercise CHO intake if the athlete competes in multiple events. During training, however, the power sport athlete may be exercising for several hours, and should therefore consume between 30-60 g/h of CHO.<sup>215,18</sup> For endurance athletes, the recommendations are specific. Rinsing the mouth with a carbohydrate solution has been shown to improve high intensity endurance performance lasting ~30-75 minutes.<sup>13</sup> See Table 2 for the breakdown of CHO needs as duration increases.

**Type**: Team sport, power sport and endurance athletes exercising ~2.5 hours, should choose a CHO source that is rapidly oxidized.<sup>1,16</sup> Sources of CHO such as glucose (dextrose), sucrose and maltodextrin are all oxidized at a rate of ~1 g/min and are appropriate choices. The form in which the carbohydrate is consumed (drink, gel or solid) does not influence oxidation rates; therefore, athletes should choose the form that works best for them.<sup>14,15</sup>

Pre-exercise 1-4 hours	1-4 g/kg bodyweight (0.45-1.82 g/lb)
Pre-exercise <1 hour	If desired, a small amount of easily digested carbohydrate, in an amount and form the athlete prefers
During exercise	Team and power sports: 30-60 g/h Endurance sports: Dependent upon duration up to 90 g/h (See Table 2)
Post-exercise <8 hours to recover	1-1.2 g/kg bodyweight/hour (0.45-0.55 g/lb) for the first 4 hours, then resume daily fueling needs
Post-exercise >8 hours to recover	Daily fueling plan adequate to restore muscle glycogen (assuming adequate carbohydrate intake)

**Table 3**: Sports nutrition carbohydrate recommendations

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Endurance athletes exercising >2.5 hours should consume up to 90 g of CHO/h and choose a 2:1 blend of glucose and fructose. This blend will take advantage of the multiple transport systems in the gut. This results in high oxidation rates of the exogenous CHO for fuel and may reduce the risk of GI distress. For more information on multiple transportable CHOs, please see Sports Science Exchange #108 "Multiple Transportable CHOs and Their Benefits," as well as Sports Science Exchange #178 "Training the Gut for Athletes" by Dr. Asker Jeukendrup. Both can be found at gssiweb.org.<sup>11</sup>

While the focus here is carbohydrate, it is important to note that during exercise athletes also need to maintain hydration. It is important for athletes to develop and practice a sports nutrition plan that appropriately combines carbohydrate for fuel as well as fluid for hydration in relation to the type of sport, duration, goals and environment.

#### CARBOHYDRATE AFTER TRAINING & COMPETITION

The goal of post-exercise CHO intake is to replenish glycogen stores. The timing and amount of CHO intake post-exercise depends on the recovery time. If the athlete plans to practice, train or compete again within 8 h,<sup>2,15</sup> attention should be paid to replenishing glycogen stores. The athlete should consume 1-1.2 g of CHO/kg/hour (0.45-0.55g/lb/hour) every hour for the first 4 hours and then resume regular dietary habits in order to quickly refuel glycogen stores.<sup>2,15</sup> While consuming CHO post-exercise

is still a good habit for athletes with a greater amount of recovery time, meeting daily CHO needs should be adequate to restore muscle glycogen. Unless the athlete follows a low-carbohydrate diet, muscle glycogen stores can generally be normalized within 24 hours.<sup>3</sup>

Any opinions or scientific interpretations expressed in this document are those of the author and do not necessarily reflect the position or policy of PepsiCo, Inc.

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