International Journal of Sport Nutrition and Exercise Metabolism, 2026, 36, 215-232
https://doi.org/10.1123/ijsnem.2025-0239

Human Kinetics
SCHOLARLY REVIEW

UCI Sports Nutrition Project: Race Nutrition for Road Cycling

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This review outlines recent advances in race nutrition support for professional road cycling, emphasizing individualized, context-specific strategies over generic recommendations. Within the past couple of decades, there have been several changes in nutritional demands and practices within road cycling including (1) a change in the distribution of intensity across a stage or 1-day race; (2) an increase in "on-bike" carbohydrate intake coinciding with integrated "training the gut" practices; and (3) better maintenance of neutral energy balance across stage races. Specifically, race tactics now, generally demand a higher intensity earlier within a stage (or 1-day race), thereby also increasing energy and carbohydrate requirements and utilization early on within a stage. Concomitantly, there has been an increase in reported intake of carbohydrates "on-bike," from ~30 to 60 g/hr pre-2010, to 90 and even 120 g/hr and higher in the present day. There is also evidence that the maintenance of energy balance across stage races has improved over this timeframe. These topics are discussed in detail alongside additional nutritional challenges and strategies relevant to professional road cycling, such as daily energy, fluid, and macronutrient distribution, which are often tailored to rider characteristics (e.g., body size, role, performance goals) and race-specific factors (e.g., course profile, environmental conditions).

Keywords: supplements, carbohydrates, performance nutrition, elite athletes, cyclists

With road race durations ranging from a few minutes (e.g., short time trials or prologues) to ~7 hr (e.g., the so-called "classics," or "monuments," or longer stages in stage races), the power outputs produced by individual riders across the event are highly variable and influenced by stochastic race demands (Valenzuela et al., 2025). The vast majority of time is spent in low to moderate intensities (i.e., below lactate threshold or below 85% wattage max [$W_{\max}$]; Lamberts et al., 2024; Sanders & Heijboer, 2019). However power output is highly variable during races and success in these races is usually decided either by the ability to generate a large power output as part of an explosive sprint, or by maintaining a high power output for a relatively long period of time, such as forcing a breakaway or attacking on a climb (Lamberts et al., 2024; Menaspà et al., 2017; Mujika & Padilla, 2001).

As a weight-bearing, endurance sport competed across a variety of terrains, key determinants of successful road cycling performance include management of body mass (BM; i.e., power-to-mass ratio), appropriate fueling to maintain the capacity to produce power, dealing with extreme environmental conditions (e.g., altitude, heat, and cold), prevention of illness and injury, and other ergogenic nutritional strategies to optimize power-to-mass ratio across an endurance event (e.g., supplements). Nutrition plays a key role in all of these areas, with energy balance and protein intake dictating long-term changes in BM and composition, carbohydrate availability being the limiting fuel for endurance events, nutritional demands being altered by environmental conditions (Cheung et al., 2025), adequate nutritional status and good food hygiene practices minimizing risk of illness and injury (Wilson et al., 2025), in addition to the potential for nutritional supplements to enhance performance via several different mechanisms (Whitfield et al., 2025). Since environmental conditions, illness and injury, and supplements are covered by other reviews in this series, the current review will focus on the other key nutritional aspects to professional road cycling, namely energy and macronutrient metabolism with discussion of the changes that have occurred within road cycling nutrition in the past two decades.

Fundamentals of Energy and Macronutrient Metabolism for Road Cycling

Energy Expenditure

Total energy expenditure is primarily comprised of three components: (1) resting metabolic rate—the energy required to maintain homeostasis under resting, fasted conditions; (2) thermic effect of feeding—the energy required to ingest, digest, absorb, and metabolize food and beverages; and (3) physical activity energy expenditure—the energy associated with skeletal muscle force production (which includes exercise). Resting metabolic rate is primarily determined by fat-free mass, the thermic effect of feeding is primarily determined by the amount and composition of the diet, and physical activity energy expenditure is primarily determined by the amount of skeletal muscle force production in addition to

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efficiency. Most of this will be on-bike and is usually recorded through power meters on the bike and a relatively small of physical activity or exercise off the bike. Within an individual road cyclist, physical activity energy expenditure is quantitatively the most variable component and therefore mostly dictates the day-to-day changes in total energy requirements. On a rest day, physical activity energy expenditure could be less than 500 kcal/day, whereas with Monuments and some of the longest stages of a Grand Tour, physical activity energy expenditure can exceed 7,000 kcal/day (Ebert et al., 2007; García-Rovés et al., 1998; Muros et al., 2019; Saris et al., 1989; Van Hooren et al., 2023). This results in the typical average energy expenditure across a Grand Tour of 5,000–6,000 kcal/day in men (Ebert et al., 2007; García-Rovés et al., 1998; Muros et al., 2019; Saris et al., 1989; Van Hooren et al., 2023). At present, data in elite women are lacking; however, energy expenditures are estimated to be ~10%–30% lower because of shower duration stages and lower average power outputs. Maintaining energy balance across a Grand Tour is therefore one key nutritional challenge to minimize changes to body composition and the capacity to produce power.

Carbohydrate Metabolism

While exercise increases total energy expenditure, the increase above rest is primarily covered by increases in carbohydrates and fat oxidation rates. While both carbohydrates and fat make important contributions to energy expenditure during exercise intensities and durations of road cycling, the relevance of fat intake is less than that of carbohydrates for several reasons. First, whereas carbohydrates are a limited store of energy (typically < 4,000 kcal available in a lean athlete), fat stores are practically limitless with respect to acute exercise demands (>50,000 kcal even for lean athletes; Gonzalez et al., 2016). Second, whereas both carbohydrates and fat can fuel low-to-moderate exercise intensities, carbohydrate becomes a predominant fuel for moderate- to high-intensity exercise (van Loon et al., 2001). Carbohydrates have several advantages at these intensities: They are the most oxygen efficient fuel and have the fastest capacity for ATP resynthesis (Frayn, 1983; Lim et al., 2011). Maintaining high carbohydrate availability can therefore have several advantages, from delaying the depletion of glycogen, through to maintaining euglycemia, and high rates of carbohydrate oxidation with the associated increases in oxygen efficiency and capacity for rapid ATP resynthesis (Lim et al., 2011; Ravikanti et al., 2025).

Protein Metabolism

Protein plays important roles for several physiological systems. Of most relevance to road cycling is skeletal muscle turnover and immune function. Skeletal muscle turnover is regulated by both exercise and nutrition. Of the nutritional factors, protein is the most potent stimulus for skeletal muscle protein synthesis (Gorissen et al., 2015). Ingestion of protein provides the signal and substrate for stimulating muscle protein synthesis (Gorissen et al., 2015). In turn, muscle protein synthesis is crucial for muscle reconditioning and adaptation. With road cycling races lasting > 5 hr, it is relevant to question whether cyclists should ingest protein “on bike” in order to produce an immediate effect and/or to contribute to daily protein requirements. Whereas, protein ingestion postexercise clearly stimulates skeletal muscle (bulk and mitochondrial) protein synthesis (Trommelen, van Lieshout, Pabla, et al., 2023), protein ingestion during exercise typically does not increase protein synthesis within active muscle (Beelen et al., 2008, 2011; Hulston et al., 2011). Although protein ingestion during exercise may still stimulate protein synthesis in other muscles and contribute to whole-body protein balance (Hulston et al., 2011; Koopman et al., 2004), the importance of this is unknown. Since the intake of protein can also inhibit gastric emptying and thereby delay the delivery of exogenous carbohydrated and fluids to the muscle, and there is no good evidence of an immediate beneficial effect on active muscle or performance (van Loon, 2014), this practice is generally not recommended.

Recent Advancements in Nutritional Demands and Practice in Road Cycling

Race Strategy and Nutritional Demands

Average speeds in professional road races have increased in recent years (Figure 1), due partly to advances in equipment, but also because races are now contested at higher intensities from the outset. Correspondingly, mean power outputs during competition has risen (Berg, 2025). This increase appears to be driven at least partly by tactical team strategies that deliberately elevate race intensity early in the event to induce fatigue (personal communication, Jeukendrup, Redegeld, Martins). Such approaches exploit the observation that performance differences between recreationally trained (i.e., Tier 1 and Tier 2; McKay et al., 2022) cyclists becomes increasingly pronounced as fatigue accumulates (Van Erp et al., 2021).

The increasingly aggressive nature of contemporary road racing has important implications for nutrition requirements. Overall energy expenditure is elevated and the relative contribution of carbohydrates for energy provision is also increased. As a result, teams have placed greater emphasis on strategies to optimize carbohydrate availability during competition. Nutrition support is increasingly recognized as a critical performance factor in road cycling (Jeukendrup, 2004, 2011). Since there are companion

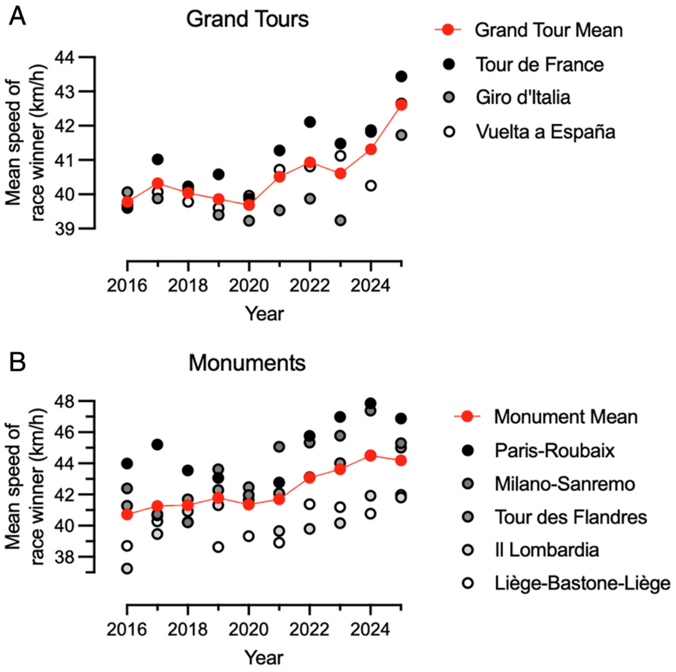

Figure 1 — Mean speed of race winners in grand tours (A) and monuments (B) between 2016 and 2025.

reviews within this series that summarize: (1) nutritional strategies to enhance adaptation and recovery from cycling (Morton et al., 2025), (2) advancements in nutritionally-relevant technologies in cycling (Gonzalez et al., 2025), and (3) supplements relevant to cycling (Whitfield et al., 2025), the focus of this review is on factors that are relevant for race nutrition. A notable difference with road cycling (especially stage racing) as compared with other endurance sports where competitions are less frequent (e.g., marathon running), is that within race/stage nutrition requires the additional consideration of managing glycogen, hydration, and BM from racing on the day(s) prior to, and in preparation for racing on upcoming days.

Progression in Nutritional Practices

One of the most prominent nutritional developments in professional cycling in the last 10–20 years has been the gradual increase in carbohydrate intake during competition. Prior to 2000, intake rates of ~23 g/hr were commonly reported (García-Rovés et al., 1998). Intake rates increased between 2004 and 2010 following publication of a series of studies demonstrating performance with increasing delivery of carbohydrates, however few athletes were exceeding 60 g/hr (Havemann & Goedecke, 2008; Pfeiffer et al., 2012). In more recent years, however, the vast majority of WorldTour riders have adopted intake of 90 g/hr (Muros et al., 2019) with emerging practices of 120 g/hr or even higher in selected race contexts (personal observations, Jeukendrup, Redegeld, & Martins, 2025).

Several factors appear to explain this shift toward higher carbohydrate intake during races which include both advancements in knowledge of carbohydrate absorption during exercise and its contribution to race fueling and performance, in addition to the role of on-bike carbohydrate intake in supporting day-to-day recovery and managing energy balance. The results of studies published between 1989 and 2025 are summarized in Table 1, reporting daily energy and carbohydrate intake during stage races or series of 1-day races, as well as on-bike carbohydrate intake. Although an early report of four riders in the Tour de France suggested the intake of large amounts of carbohydrate during stages (~90 g/hr; Saris et al., 1989), this did not seem to be a common practice in those days. Indeed, the priority given to the tactical needs of racing was a proposed explanation for reports from the 1998 Vuelta a España of on-bike carbohydrate intake of ~23 g/hr (range 9–39 g/hr) during 4- to 5-hr stages. Here, most of the daily energy and carbohydrates were consumed at breakfast and after stages (García-Rovés et al., 1998). A focus on optimizing carbohydrate intake within races (i.e., on the bike) has, however, increased across time, with a 2008 study reporting an average of 64 g/hr in World Tour riders (Pfeiffer et al., 2012), and 63 g/hr (range 28–145 g/hr) in competitive (but not World Tour level) cyclists (Havemann & Goedecke, 2008). More recent work showed an even higher average intake of 91 g/hr (range 66–119 g/hr) during the Vuelta a España (Muros et al., 2019), while contemporary riders in World Tour teams are now commonly ingesting 90–120 g/hr, and targeting 120 g/hr or above during hard stages (personal observations, Jeukendrup, Redegeld, & Martins, 2025). While reported on bike carbohydrate intake have increased over time, the reported total daily carbohydrate intake have remained relatively stable on average (~13 $g\cdot kg^{-1}\cdot day^{-1}$; Table 1; Figure 2), reflecting this shift in pattern and timing of carbohydrate ingestion.

Table 1 Available Literature in Energy and Carbohydrate Intake During Stage Races in Professional Cyclists

Reference	Participants	Race period	Daily energy intake
Saris et al. (1989)	Male professional WorldTour riders ($n = 4$)	Tour de France (3-week stage race)	5,903 ± 574 kcal
García-Rovés et al. (1998)	Male professional WorldTour riders ($n = 10$)	Vuelta a España (3-week stage race)	5,617 ± 430 kcal
Ebert et al. (2007)	Male national professional riders ($n = 8$)	Tour Down Under (6-day stage race)	–
Rehrer et al. (2010)	Male national professional riders ($n = 4$)	Tour of Southland (10 stages over 6 days)	6,524 ± 908 kcal
Pfeiffer et al. (2012)	Male professional WorldTour riders ($n = 8$)	Dauphiné Libéré (8-day stage race) and Vuelta a España (3-week stage race)	–
Ross et al. (2014)	Male international professional riders ($n = 5$)	Tour of Gippsland (nine stages over 5 days) and Tour of Geelong (six stages over 5 days)	–
Sánchez-Muñoz et al. (2015)	Male UCI Continental riders ($n = 6$)	Tour of Andalucia (4-day stage race)	5,644 ± 593 kcal
Fordyce (2018)	Male professional WorldTour rider ($n = 1$, Chris Froome)	Two stages of Giro d'Italia (Stages 11 and 19 during 3-week stage race)	Stage 11 (flat): 2,466 kcal Stage 19 (mountain): 6,663 kcal
Muros et al. (2019)	Male professional WorldTour riders ($n = 9$)	Vuelta a España (3-week stage race)	5,415 ± 567 kcal
Heikura et al. (2019)	Male professional WorldTour riders ($n = 6$)	Four single–day races in 8-day period ("Spring Classics")	6,216 ± 789 kcal
Strobel et al. (2022)	Male professional WorldTour rider ($n = 1$)	Vuelta a España (3-week stage race)	–
Areta et al. (2024)	Female professional WorldTour rider ($n = 1$)	Tour de France Femmes (8-day stage race, data collection was during first seven stages)	5,246 kcal

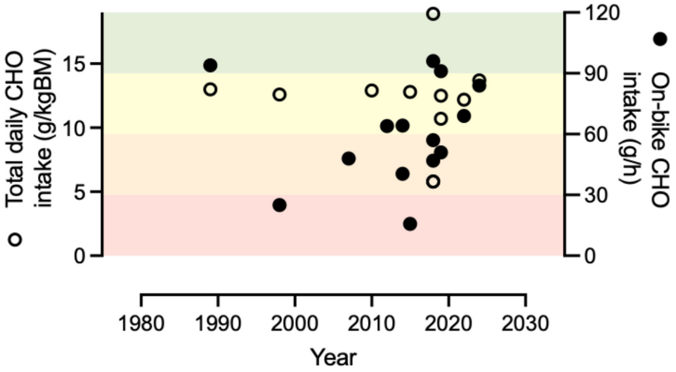

Figure 2 — Total daily and on-bike carbohydrate (CHO) intake in professional cyclists reported across time. See Table 1 for references.

Daily carbohydrate intake, and the timing of that intake are likely the most important determinants of muscle glycogen restoration between races, and in preparation for subsequent competition (Burke et al., 2017). Effective management of carbohydrate intake requires an understanding of the specific context including an estimation of the amount of carbohydrate oxidized during the preceding stage or training session, the time available for recovery, and the additional carbohydrate required to maximize glycogen resynthesis. These considerations must be integrated with overall intake of protein and nutrients. Optimal protein intake is dependent on the amount (Trommelen, van Lieshout, Nyakayiru, et al., 2023) but also the distribution of intake throughout the day. Because carbohydrates, protein, and fat (which makes up the remaining energy intake) requirements are dependent on different variables and need to be considered within a daily 24-hr context, this adds complexity that cannot be captured by generic one-size-fits all guidelines. Instead, effective implementation requires practitioner expertise to appropriately translate scientific evidence into practical advice with a sound understanding of exercise metabolism.

The advances in carbohydrate intakes and other nutritional developments in cycling have been made possible by increased team investment in logistical and nutritional support. Many professional teams now employ multiple chefs and sports dietitians/nutritionists as part of their performance staff, operate kitchen trucks or vans and partnerships with nutrition brands. In parallel, dedicated software platforms (desktop as well as smartphone-based applications) have been developed to estimate energy, carbohydrate, and protein requirements, monitor actual dietary intake, and in some cases may integrate with supermarket supply chains to facilitate the timely delivery of food items and ingredients to the team. These modern solutions to nutrition in order to meet individualized nutrition goals in high-demand situations are covered in more detail in a companion review (Lis & Strobel, 2025).

Racing

Preparation for 1-Day Versus Stage Races

While carbohydrate loading is a strategy often discussed in the context of other endurance sports where there are fewer race days and no stage races, the preparation days in road cycling usually coincide with recovery from a previous training session or race day. The goal is always to optimize glycogen stores in muscle and liver but there is not really a defined preparation period due to the day-to day racing schedule of road cycling (in contrast to marathon runners for example who prepare specifically for a limited number of races). “Fuel for the work required” is therefore more appropriate to describe the days leading up to a specific race/stage (Impey et al., 2018; Morton et al., 2025).

For one-off events, glycogen loading protocols might be appropriate, albeit modified from traditional protocols. Whereas, traditional protocols required 3 days of restricted carbohydrate intake followed by a similar period of high carbohydrate intake to facilitate glycogen supercompensation (Bergström & Hultman, 1966; Hultman & Bergström, 1967), the depletion phase appears unnecessary in trained athletes (Sherman et al., 1981), and the time course for maximizing muscle glycogen stores is likely 24–36 hr (Bussau et al., 2002) especially in highly trained athletes (Greiwe et al., 1999). Furthermore, maximizing liver glycogen stores appears to be possible within 12 hr with aggressive carbohydrate ingestion protocols (Fuchs et al., 2016, 2025). Therefore, the general recommendation for achieving optimal muscle glycogen stores prior to single-day long races is to consume 10–12 g/kg BM per day for 1–2 days prior to competition (Burke, van Loon, Hawley, 2017), with additional allowances for carbohydrate use during any training sessions performed on these days. Not only does this relate to one-off events, but this also has relevance to stage races, where the typical recovery period between stages (also reflecting preparation for the next stage) is ~18 hr. Therefore, the restoration and management of glycogen stores is crucial for stage racing but is achievable with appropriate nutritional strategies. One could argue that if 18–20 hr is insufficient to restore glycogen sufficiently, one would see performance decrements over time; however, this is usually not observed in stage races. Although mixtures of fructose and/or galactose with glucose-based carbohydrates can accelerate liver glycogen restoration compared with just glucose-based carbohydrates (Achten et al., 2004; Décombaz et al., 2011; Fuchs et al., 2016; Podlogar et al., 2022), it is unclear whether such mixtures can result in performance benefits in certain situation. More research is therefore needed to specifically investigate the potential recovery and performance aspects of such carbohydrate mixtures, and whether this differs between elite and lower caliber cyclists.

Energy Management in Stage Races

The energy and carbohydrate requirements of road cycling are unique among endurance sports, and even within most of the cycling disciplines. Specifically, road races are contested over a variety of distances and durations ranging from single-day events to multistage races that take place across 3 weeks. For this reason, this review focuses on the strategies used to calculate needs and achieve intakes that are substantially higher than in many other sports. Indeed, in some stage races, estimated energy needs may be up to four to five times the daily basal metabolic rate (Ebert et al., 2007; Saris et al., 1989; Valenzuela et al., 2025; Westerterp et al., 1986). Summaries of reported energy characteristics of professional riders in multiple-day races, especially Grand Tours (Table 1), show energy intake and/or expenditures of 5,500–9,000 kcal/day for up to 21 consecutive days, with just two rest days during Grand Tours (Ebert et al., 2007; García-Rovés et al., 1998; Muros et al., 2019; Saris et al., 1989; Van Hooren et al., 2023).

Meeting these high energy intake requirements can be both logistically and biologically challenging; logistically in terms of the practicalities of preparing and delivering the volumes and quality of food required to meet cyclists heightened nutritional demands, and biologically in terms of ensuring that a rider’s gastrointestinal system is capable of tolerating, absorbing, and distributing ingested nutrients to all biological systems. This requires coordinated efforts among cyclists, nutritionists, coaches, and culinary staff and in recognition of both the importance of fueling, and these challenges, professional teams tend to invest heavily in providing appropriate nutritional support to their riders. These nutritional support teams have developed a range of on- and off-bike strategies to optimize energy and carbohydrate intake throughout the day. Such practices are important in racing scenarios, but also during periods of intensified or specialized training (e.g., altitude training camps—see Cheung et al., 2025 for additional details). For example, a study found that ad libitum intake during 8 days of intensified training in cyclists resulted in a lower carbohydrate and energy intake compared with a carbohydrate supplemented group, resulting in reductions in performance and an increase in overreaching symptoms (Halson et al., 2004). In a similar training study where energy intake was controlled, a group receiving lower carbohydrate intake demonstrated reductions in performance and an increase in overreaching symptoms (Achten et al., 2004). These studies demonstrate the importance of maintaining carbohydrate and energy balance outside competition scenarios.

Carbohydrates

Incorporating the "fuel for the work required" paradigm (Impey et al., 2018; Morton et al., 2025) is therefore critical in road cycling given the relative intensity of races varies based on course profile, environmental conditions, and duration, with additional differences between riders based on their role within a team (e.g., domestiques vs. general classification riders). Indeed, race-day carbohydrate intake has been reported to range from 5 to 22 g/kg BM. This is exemplified by the case study of 2018 Giro d'Italia winner, Chris Froome, which revealed his breakfast contained 1.1 g/kg BM carbohydrate at breakfast prior to easier stages, compared with 2.7 g/kg BM carbohydrate in preparation for harder mountain stages (Fordyce, 2018). During the stage itself, carbohydrate intake on the bike was higher during the hard mountain stages (96 g/hr) than on the relatively easy stages (57 g/hr). During recovery, he consumed 0.7 g/kg BM carbohydrate in the acute postrace period with a similar amount consumed at dinner, whereas following "harder" days, he consumed 6.3 g/kg BM carbohydrate with another 2.7 g/kg BM carbohydrate consumed at dinner (Fordyce, 2018). More recently, a case study was published highlighting meal-by-meal carbohydrate periodization for one rider during a full Grand Tour (Strobel et al., 2022). A weighed food diary revealed total daily carbohydrate intakes ranging from 5.1 to 17.7 g/kg BM, while on-bike carbohydrate intake ranged from 41 to 106 g/hr. Carbohydrate intake, both on and off the bike, were highest on the days with the highest on bike energy expenditure (Strobel et al., 2022). However, we note that a limitation with the evidence base at present is the lack of peer-reviewed reports. Indeed, many detailed weighted food records collected across races and training camps in professional cycling teams remain unpublished (personal observations, Redegeld, Martins, & Jeukendrup, 2025). Therefore, it should be noted that the currently published literature only represents a specific snapshot of road cycling. In our own observations the average daily carbohydrate intake of eight riders during a Grand Tour ranged from 9.6 to 18.5 g/kg BM between days, with individual peaks up to 22.2 g/kg BM on the most-demanding day (personal observations, Redegeld, Martins, & Jeukendrup, 2025). Average carbohydrate intake on the bike ranged from 10 g/hr on rest days to 120 g/hr during the most demanding stages (personal observations, Redegeld, Martins, & Jeukendrup, 2025). While there is limited published evidence in professional female cyclists, one case study demonstrated similar carbohydrate periodization during the Tour de France Femmes, with daily intake ranging from 9.7 to 15.9 g/kg BM and on bike intake ranging from 68 to 105 g/hr (Areta et al., 2024). More data are needed in female cyclists with measures of changes in energy stores, and energy expenditure, as well as reported energy intake.

Daily carbohydrate intake requirements depend on many factors such as training duration, intensity, and environmental conditions. These factors will determine the overall total energy requirements for the individuals, which in turn will dictate daily carbohydrate targets. Tables 2 and 3 show the different ranges of carbohydrate requirements based on current recommendations for both amateur and professional male and female cyclists including an example of a Grand Tour stage with carbohydrate intake targets of 120 g/hr. The total carbohydrate largely depends on the chosen macronutrient distribution of energy intake coupled with the target ingestion rates for carbohydrates during training or racing. As observed in Table 3, daily carbohydrate quantities relative to BM can vary widely, and these must be adapted and tailored according to the total duration and intensity of a specific session. These calculations are based on assumptions and estimations of substrate use calculated based on power meter data coupled with individual pedaling efficiency measurements collected in a laboratory via indirect calorimetry (Gonzalez et al., 2025), where generally the goal is to achieve energy and carbohydrate balance (i.e., matching energy and carbohydrate intake to expenditure). However, specific carbohydrate needs are more difficult to establish or to predict, but mathematical modeling and machine learning may be used to

Table 2 Total Amount of Recommended Daily Carbohydrate Intake in Absolute (in Grams) and Relative to Body Mass (in Grams per Kilogram) for Male Cyclists, Training/Racing Duration and Intensity

	Type of event/duration			
Training level	**1-hr easy spin** 0–30 g/hr carbohydrate during exercise	**3-hr endurance training** 60 g/hr carbohydrate during exercise	**5-hr race intensity** 90 g/hr carbohydrate during exercise	**5:30-hr Grand Tour stage** 90–120 g/hr carbohydrate during exercise
Amateur cyclist *Male; 75 kg; 180 cm; 29 years*	**Average power: 170 W** 330–585 g (4.4–7.8 g/kg) carbohydrate	**Average power: 200 W** 705–1020 g (9.4–13.6 g/kg) carbohydrate	**Average power: 240 W** 1350–1425 g (18–19 g/kg) carbohydrate	–
Professional cyclist *Male; 67 kg; 180 cm; 29 years*	**Average power: 190 W** 299–520 g (4.6–8.0 g/kg)	**Average power: 220 W** 637–923 g (9.8–14.2 g/kg) carbohydrate	**Average power: 260 W** 1235–1365 g (19–21 g/kg) carbohydrate	**Average power: 280 W** 1573–1651 (24.2–25.4 g/kg) carbohydrate

Note. Basal metabolic rate estimated using ten Haaf equation (ten Haaf & Weijs, 2014). Physical activity level for both individuals set at 1.55; pedaling gross efficiency 23%.

Table 3 Total Amount of Recommended Daily Carbohydrate Intake in Absolute (in Grams) and Relative to Body Mass (in Grams per Kilogram) for Female Cyclists, Training/Racing Duration and Intensity

	Type of event/duration			
Training level	**1-hr easy spin** 0–30 g/hr carbohydrate during exercise	**3-hr endurance training** 60 g/hr carbohydrate during exercise	**4-hr race intensity** 90 g/hr carbohydrate during exercise	**4:30-hr Grand Tour stage** 90–120 g/hr carbohydrate during exercise
Amateur cyclist *Female; 61 kg; 165 cm; 25 years*	**Average power: 130 W** 275–476 g (4.4–7.8 g/kg) carbohydrate	**Average power: 150 W** 520–730 g (8.5–12 g/kg) carbohydrate	**Average power: 170 W** 735–980 g (12–16 g/kg) carbohydrate	-
Professional cyclist *Female; 53 kg; 165 cm; 25 years*	**Average power: 150 W** 240–425 g (4.5–8.0 g/kg)	**Average power: 170 W** 480–660 g (9.0–12.5 g/kg) carbohydrate	**Average power: 190 W** 680–890 g (12.8–16.8 g/kg) carbohydrate	**Average power: 210 W** 910–1170 (17.1–20 g/kg) carbohydrate

Note. Basal metabolic rate estimated using the ten Haaf equation (ten Haaf & Weijs, 2014). Physical activity level for both individuals set at 1.55; pedaling gross efficiency 23%.

estimate glycogen use (Akberdin et al., 2021; Jagnesakova et al., 2022; Rothschild et al., 2025) based on noninvasive data and training-load metrics routinely collected by athletes and coaches (e.g., heart rate, power output, rating of perceived exertion), or exercise duration. Other models are available in training applications (e.g., TrainingPeaks) or are proprietary to the software a cycling team uses. However, in all cases, individual measurements and larger data sets can make predictions more accurate and personalized, noting that models may not account for the stochastic nature of racing which features long bouts of steady-state exercise punctuated by short periods of heavy or severe intensity exercise.

Acute Body Mass Manipulation (“Making Weight” Techniques in Cycling)

Athletes in weight division sports commonly undertake acute BM manipulations in the days per week prior to the weigh-in for their event, aiming to achieve the performance advantages of competing in a lower division (Artioli et al., 2010; Zhong et al., 2024). Such practices known as “making weight” often include or target shifts in body compartments (e.g., fluid or gut contents) to lower BM rather than true changes in body composition (Burke et al., 2021). These strategies may be applicable in professional cycling to help achieve the highest possible power to mass ratio for a specific stage or race, without compromising health and risk of injury. Particular interest may be demonstrated by time trial specialists during uphill time trials. Traditionally, individuals in other sports may induce rapid BM loss strategies by restricting carbohydrate intake to reduce muscle glycogen content and consequently reduce BM (given each gram of glycogen is stored with ~3–4 g of water) as well as lowering fiber intake (Reale et al., 2017). Given the substantial reliance on high carbohydrate intake to support performance in cycling races, any form of carbohydrate restriction during a (longer) racing event could significantly compromise the cyclists’ ability to perform optimally. Dehydration is another strategy that is high risk from a performance point of view and therefore not often used or recommended. However, reducing the fiber content of the diet appears to reduce the fecal intestinal bulk and water content of the bowels (Chen et al., 2020), which could result in significant reductions in BM (Burke et al., 2019; Foo et al., 2022) without resorting to other potentially performance-impairing BM loss strategies such as fluid or carbohydrate restriction. Evidence to support the use of low-fiber diets as a reliable strategy to acutely reduce BM in athletes is scarce. Nevertheless, one study has reported significant reductions in BM (~0.40 kg) with very low-fiber intake (<10 g per day) for 4 days, which became even more pronounced after 5 days (0.58 kg) when compared with a control diet with ~30-g fiber (Foo et al., 2022). Further BM reductions of up to 1 kg have also been reported elsewhere (Burke et al., 2019) and in practice (personal observations, Jeukendrup, Martins, & Redegeld, 2025).

Even though this strategy appears promising as an acute way of reducing BM while allowing cyclists to hit their energy and macronutrient targets, caution should be exercised when applying it during stage racing. Low-fiber diets considerably reduce food variety by removing fiber-containing foods like most fresh fruits and vegetables, which could reduce the micronutrient density of the diet. In addition, lower satiety, decreased stool softness, and reduced bowel movements per day could also be experienced by athletes undergoing low fiber, which are important factors to consider (Foo et al., 2022). Nutritionists should be aware of the timing of application of such diets (2–4 days), the total amount of fiber (<10 g), and how to work alongside chefs to create food choices that minimize micronutrient reductions when applying low-fiber diets. Examples of foods to consume and avoid on a low-residue diet are provided in Table 4.

An additional or alternative strategy to manipulate BM involves an acute change in salt (sodium) intake to manipulate body water content. Just as an acute intake of salt is often used as a mechanism to hyperhydrate (Savoie et al., 2015; Siegler et al., 2022), reductions of salt in the diet will have the opposite effect and thereby result in BM loss. Again, it is important to consider the potential negative consequences of salt/water reduction efforts (e.g., reduced plasma volume), and a careful risk benefit analysis should be performed to determine the strategy for specific situations for each individual rider.

In-Race Nutrition

Road cycling is unique among the cycling disciplines and other endurance events for both the requirements and opportunities for nutrition support during the race. Ingesting carbohydrates and fluid during stages will not only support performance that day, but it also helps significantly toward managing overall energy and nutrient needs over the course of 1–3 weeks of stage racing. This may occur to a lesser extent in other cycling disciplines (Oosthuyse et al., 2025; Whitfield et al., 2026) where events are shorter and/or there are logistical constraints to accessing or consuming nutritional support during the race (i.e., no support cars/staff on course). The approach to 1-day races is similar to stage races, with protocols before and during the race being adjusted according to the anticipated duration and workload.

Table 4 Options for Supporting a Low-Fiber, Low-Residue Diet

Food groups	Permitted foods	Food to limit or avoid
Starchy carbohydrates	White rice, white pasta (ensure fresh cooking), rice noodles, refined cereals (e.g., Cornflakes, Rice Krispies) Peeled and cooked potatoes, carrots, and pumpkin.	Brown rice, whole grain pasta, cooked and cooled pasta (any kind), whole wheat bread, oats, bran cereals.
Fruits	Ripe bananas, apple sauce, peeled and seedless peaches, pears, melon.	Dried fruits, fruits with skin and or seeds.
Vegetables	Beetroots, asparagus, tomato sauce (skins removed).	Raw vegetables (broccoli, cabbage, corn, onions, celery). Tomato skins.
Protein	Skinless chicken, turkey, fish, lean beef, eggs, tofu, and shellfish. Smooth peanut butter.	Fatty meats, fried meats, legumes, crunchy peanut butter. Limit sources of lactose (e.g., maximum of two cups of milk per day).
Other carbohydrates	Plain cakes and pancakes, jelly, custard, and sweets/candies.	Popcorn, whole-meal biscuits, chocolate with nuts/fruit.

Carbohydrate Intake During Races

It has long been recognized that carbohydrate intake during exercise can delay fatigue and improve endurance exercise performance (Coggan & Coyle, 1989; Coyle, 1992; Coyle et al., 1986). As demonstrated in Table 1, carbohydrate intake during cycling races has been common practice since the 1980s, supported by contemporary studies which showed that carbohydrate feeding during exercise helped maintain blood glucose and high rates of muscle carbohydrate oxidation. These studies, and later work (Coggan & Coyle, 1989; Coyle, 1992; Coyle et al., 1986) reported no evidence of exogenous carbohydrate intake on muscle glycogen breakdown, suggesting that the ingested carbohydrate was sparing liver glycogen. Subsequent studies have supported this theory, with tracer methodology demonstrating complete suppression of endogenous glucose production with ingestion of large amounts of carbohydrate during cycling (Jeukendrup, Wagenmakers, et al., 1999) and magnetic resonance spectroscopy confirming the prevention of net liver glycogen depletion (Gonzalez et al., 2016).

Single carbohydrate sources (e.g., glucose or maltodextrin) are only oxidized at rates up to an average of 60 g/hr, even when rates of ingestion are much higher (Jeukendrup, 2010). Studies from 2004 to 2006 demonstrated the saturation of intestinal uptake by the glucose transporter-1 to be the limiting factor to glucose oxidation. This bottleneck could be circumvented by the co-ingestion of sugars with a different absorption mechanism (e.g., fructose), thus allowing substantially higher rates of total uptake and exogenous carbohydrate oxidation (Jentjens, Achten, Jeukendrup, 2004; Jentjens, Moseley, et al., 2004; Jentjens & Jeukendrup, 2005; Wallis et al., 2005). Subsequent work has demonstrated that consumption of such “multiple transportable carbohydrate” sources, which rely on different transport proteins for absorption in the gut results in significant performance benefits compared with ingestion of a single carbohydrate source (Currell & Jeukendrup, 2008; Rowlands & Houltham, 2017; Triplett et al., 2010). Nutritional recommendations for events longer than 2.5 hr were therefore amended to 90 g/hr (Jentjens, Achten, Jeukendrup, 2004; Jentjens, Moseley, et al., 2004; Jentjens & Jeukendrup, 2005; Jeukendrup, 2004, 2010, 2011; Jeukendrup et al., 1999; Wallis et al., 2005) given 90 g/hr seemed to be relatively well tolerated by most study participants, whereas higher intake often resulted in more gastrointestinal complaints. Studies involving higher rates of intake (e.g., 144–180 g/hr) also seemed to suppress fat metabolism without reducing endogenous carbohydrate oxidation (Jentjens & Jeukendrup, 2005; Jeukendrup, Raben, et al., 1999), findings later confirmed in a study comparing intakes of 90 g/hr versus 120 g/hr (Podlogar et al., 2022).

Sports foods manufactured for in-race intake (e.g., sports drinks, and gels) now offer specialized formulae for use in scenarios requiring high fueling rates. As summarized in the companion piece on sports foods and supplements (Whitfield et al., 2025), endurance-focused sports products routinely involve glucose and fructose blends to take advantage of multiple absorption rates. New carbohydrate molecules, including trehalose (Venables et al., 2008), isomaltulose (Achten et al., 2007), and high molecular weight glucose polymers (Rowlands et al., 2005; Rowlands & Clarke, 2011) have also been introduced, while commercial products with added fibers (pectin and alginate) which create a hydrogel in the stomach are claimed to achieve faster gastric emptying and muscle carbohydrate delivery (Barber et al., 2020; Flood et al., 2020; McCubbin et al., 2020). In general, however, these solutions appear similar in terms of carbohydrate oxidation and/or performance outcomes with the multiple transportable carbohydrate (Achten et al., 2007; Barber et al., 2020; Flood et al., 2020; McCubbin et al., 2020; Rowlands et al., 2005; Rowlands & Clarke, 2011; Venables et al., 2008). Since the form of the carbohydrate (e.g., drinks, gels, chews or solid food) seems to have little or no impact on exogenous carbohydrate oxidation rates (Hearris et al., 2022; Pfeiffer et al., 2010a, 2010b), as long as they are low in fat, fiber, and protein to avoid the slowing of gastric emptying, riders can choose their race intake according to personal preference and practicality. Indeed, the provision of 90 g/hr of carbohydrates as a mixture of beverages, bars, gels, and rice cakes has been shown to improve endurance capacity relative to carbohydrate intake of 45 g/hr demonstrating the relevant translation of these guidelines using carbohydrate sources that are typically used in road cycling (Fell et al., 2021). The timing of intake over a race or stage can probably also be directed by these circumstances, since a study which provided larger boluses twice an hour versus smaller boluses eight times per hour only showed small differences in exogenous carbohydrate oxidation (Mears et al., 2020). Table 5 summarizes the range of factors that determine race fuel needs and opportunities to address them with an individualized plan, over different race formats.

It is noted that advice for carbohydrate intake during racing is still expressed as grams per hour, with similar recommendations given for male and female athletes as well as for smaller and larger athletes. This practice is based on an analysis of data from several exogenous carbohydrate oxidation studies, which demonstrated a negligible relationship between body size and peak exogenous carbohydrate oxidation rates (Jeukendrup, 2010). In contrast, the results of a recent study suggests that body size may be a factor to consider, with mean rates of exogenous glucose oxidation being

Table 5 Summary of Key Issues That Contribute to the Development and Implementation of Fueling and Hydration Plans in Road Cycling

Factors influencing race nutrition plans	Discussion	Guidelines for race fluid/fueling plan
Fuel needs	Carbohydrate requirements for a race/stage depend mostly on event duration but may have to be adjusted depending on factors such as the event workload (e.g., expected intensity, the rider's goals for the stage and for the next day, environmental characteristics, etc.) and personal preferences (Jeukendrup, 2014). To achieve these carbohydrate intakes, riders can use a mix of carbohydrate sources including drinks, gels, chews or solid foods. High fat, fiber, and protein intakes should be avoided as these may all slow down gastric emptying and the delivery of carbohydrate to the intestine. There appears to be a dose–response relationship with carbohydrate intake and performance when the riders can tolerate the feeding well. This tolerance appears to be "trainable." There is currently little evidence that increase the intake above 90 g/hr will provide additional benefit, but this has become common practice among cyclists during harder stages and races, also because this may help the recovery the day after. Additional research in this space is therefore warranted.	The race fueling plan should be developed according to the individuals needs while also accounting for race duration, as outlined below. Races of 1–2.5 hr: 30–60 g/hr Races of >2.5 hr: 90 g/hr or even higher in highly trained riders who are accustomed to such high intakes. For examples of the carbohydrate intake recommendations, see Tables 2 and 3. The carbohydrate sources should be multiple transportable carbohydrate. Elite cyclists generally push to higher intakes (>90 g/hr) during harder stages with higher energy expenditures. In these stages, riders often ingest 120 g/hr. These targets can be achieved with various carbohydrate sources (liquid, semiliquid, and solid) and it is mostly up to the riders' personal preferences and availability during the race.
Fluid losses and hydration requirements	Sweat rates are highly variable and are determined by the intensity of cycling, the environmental conditions and opportunities for convective cooling. High workloads are generally sustained in time trials, with stochastic higher intensity efforts in 1-day races/stages according to the tactics and terrain (e.g., uphill stages, breakaways/attacks/chases, and prolonged sprints). Although the workload for a given speed is reduced for cyclists in drafting positions (i.e., in a bunch/peloton), there may also be a reduction in convective cooling. Many major competitions (e.g., Olympic Games or World Championships) or races on the general UCI calendar are held in hot countries or summer conditions, with high temperatures and humidity being compounded by reflective heat from the road surface. There are few published studies of sweat rates and sweat losses during high-performance cycling, although this information is likely to be commonly collected within the sports science support for individual riders or teams. From what is available, even in temperate conditions (10–18 °C), sweat rates ranging from 0.6 to 2.0 L/hr have been reported across different male cyclists and different race formats (Ross et al., 2014). Accounts of total BM losses of 2–4.5 kg across a single road race/stage have been reported in warm-hot weather races (Atkinson et al., 2003; Ebert et al., 2007).	Knowledge about the likely or actual sweat rates for individual riders or the conditions of specific race can be useful in determining the need and characteristics of a race nutrition plan. Monitoring changes in BM across an actual event, or across similar session(s) in the preparation for an event, provides an approximation of the accrued fluid deficit, albeit uncorrected for changes due to changes in muscle fuel stores. If corrected by the mass of fluid/foods consumed during the same session (and any urine losses), an approximation of sweat rates can be made. The magnitude of the BM or "fluid" deficit, when assessed against environmental conditions can provide some guidance of fluid intake during races. For example: if a general goal is to maintain the fluid deficit < 2% BM in a race/stage, do present practices typically achieve this or is a more proactive approach needed/possible? Regularly measuring fluid losses at the end of training and races can be done to confirm riders are drinking enough or if they need to consume more.
Availability of fluids and foods during race (general)	Unlike many other sports, road cycling provides flexibility with the availability of nutrition support during a race. Riders typically have access to bottles mounted on the bike and supplies carried in their jersey pockets. In 1-day and stage races, these supplies may be supplemented by hand-offs from team cars, and individual team staff in feed zones according to specific event rules. Supplies are provided in the form of *bidons* (bottles) or *musettes* (bags) containing bottles and foods.	Riders and their teams should look at the range of options to carry and supplement the supplies that will form their event-specific hydration and fueling plans. The race infrastructure and rules provide opportunities that can be exploited to provide the amount and timing of fluids and carbohydrate sources for each individual rider. Within the team, one of the roles of *domestiques* may be to ferry supplies to the protected riders. Other tactics may be exploited to ensure that the rider is carrying their own supplies for race segments where feed zones or handoffs are prohibited (e.g., the final 20 km).

(continued)

Table 5 ***(continued)***

Factors influencing race nutrition plans	Discussion	Guidelines for race fluid/fueling plan
Event Rules for road races (https://www.uci.org/regulations/3MyLDDrwJCJJ0BGGOFzOat#part-ii-road-races)	The practicalities of fueling are also driven by the regulation of the sport, which have changed several times in recent years. The current rules for fueling from team cars and feeding zones are spelled out in articles 2.3.025 and 2.3.027 of the UCI cycling regulation for road races (UCI Regulations PART 2 ROAD RACES, 2025) and briefly summarized here. In 1-day races or stage races, the organizers can implement feeding zones which are signposted for teams to supply their riders. Feed zones must be placed approximately every 30–40 km and should be accompanied by a zone for waste situated just before and just after the feeding zone where riders can get rid of their waste. Outside these feed zones, no feeding from the side of the road is allowed. However, on hot days, the decision may be made to increase the number of feeding points. All feeding (from a car and on foot) is strictly forbidden during the 30 first and last 20 km and close to designated intermediate sprints for secondary classifications (points classification, king of mountain classification, etc.), bonus sprints, feeding zones, and in urban areas. Although organizers will try to find the best locations, in reality, feeding points are sometimes in areas where riders will pass with high speed and it is not safe to hand out bottles. This effectively reduces the number of opportunities.	
Ease of drinking/eating	The action of consuming and tolerating foods and fluids while cycling is relatively easy compared to other sports, since it can be done on the move. Exceptions to this during road races/stages include technical and fast sections, steep uphill portions, descents, when it is difficult to take the hands off the handlebars. Indeed, observations of low fluid/fuel intakes in a study of the Vuelta a España were partially attributed by the authors to aggressive riding tactics which reduced opportunities to drink (García-Rovés et al., 1998). Cold conditions can also make it difficult to open packaging or even grab a bottle.	When forming hydration/fueling plans for a specific race/stage, it is useful to identify sections of the course or periods within race tactics which provide good opportunities for intake. Riders will not always have access to drinks from the team cars and new UCI rules limiting the number of feeding points during a race (see above) have made it more challenging to achieve fluid intake recommendations.
GI comfort	It is typically easier to tolerate the intake of fluids and foods while cycling than in other sports (e.g., running) where there is more GI "jostling" (Peters et al., 1993). Exceptions to this include individuals with specific GI issues (ter Steege et al., 2012), during high-intensity exercise, especially while maintaining an aerodynamic riding position which increases abdominal pressure (de Oliveira et al., 2014), and when already dehydrated (van Nieuwenhoven et al., 2000). There are anecdotal reports of an increase in GI problems in the last week of Grand Tours, potentially attributable to sustained energy intakes at or above the suggested alimentary limit (Thurber et al., 2019).	Training the gut involves a targeted program to consume increasingly larger volumes of fluid and/or food during training sessions, particularly with intended race nutrition supplies (Jeukendrup, 2017). Such training achieves physiological changes to increase rates of gastric emptying and intestinal absorption of nutrients, improving gut comfort and the effectiveness of race feeding. At the team level, it is a challenge finding a balance between team recommendations that are easier to execute and individual recommendations that are more tailored to the needs of a particular individual (e.g., providing bespoke products to all athletes would be impossible).
Special race formats	The criterium and time-trial formats of road cycling have different considerations regarding race nutrition. Both are of shorter duration and of higher intensity, with higher sweat rates that may be amplified by reduced convective cooling due to deliberate actions to reduce air resistance (e.g., aero helmets). Tactical/technical riding in criteriums and most other road races and aerodynamic positioning in time trials limit opportunities to consume fluids/foods during the event. Some riders may shun the additional weight of a bottle cage and full bottle in some events. Nevertheless, sweat losses and hyperthermia can be appreciable when these races are conducted in hot environments.	Opportunities to drink/fuel during these shorter race formats can be considered if the physiological benefits and opportunity overlap. Alternatively, strategies involving hyperhydration (Jardine et al., 2023; McCubbin & Irwin, 2024) and/or precooling (van de Kerkhof et al., 2024) can be undertaken prior to warm-up to create a small but worthwhile buffer with core temperature and plasma volume that might allow higher work rates to be achieved during the race before reaching critical levels associated with fatigue. Hyperhydration strategies the use of glycerol and/or sodium loading (Whitfield et al., 2025). Precooling may be via internal (e.g., ice slurries) and external (e.g., ice jackets, cold water immersion) strategies. Ice socks are often used in races. It is important that such strategies are well practiced by the individual cyclist and appropriate pacing strategies are implemented during the race.

(continued)

Table 5 *(continued)*

Factors influencing race nutrition plans	Discussion	Guidelines for race fluid/fueling plan
BM manipulation	BM is an important consideration in mountainous races or race segments, due to the high correlation between hill climbing performance and the cyclist's power to weight ratio (Lucía et al., 2000). Acute race strategies include use of a low-fiber/low-residue diet to reduce the mass of gut (Mancin et al., 2025), and conservative tactics around fluid replacement to allow BM loss via "functional dehydration" (Coyle, 2004). The negative effects of hypohydration need to be balanced against the reduced BM, with one lab-based study involving a simulated hill climb finding that riding-induced dehydration in a warm environment reduced hill-climbing endurance despite reducing the power output required for a given speed (Ebert et al., 2007).	Each rider should work with their sports science team to develop a BM management plan that includes considerations for hilly stages/races. Prerace BM manipulation may involve actual body composition changes, and fueling considerations can include low-fiber/residue options. Even if deliberate fluid deficits are not part of BM considerations, it may be possible for key riders to complete a hill climb without needing to carry the mass of full bidons.

Note. GI = gastrointestinal; BM = body mass.

higher in larger athletes than smaller athletes who consumed 90 g/hr of glucose during exercise (Ijaz et al., 2025). However, since this was assessed using a single source of carbohydrate, the findings may differ to what might be observed with an optimal feeding strategy. In addition, substantial variation in exogenous carbohydrate oxidation rates remained unexplained, with individuals of similar BM displaying large variance (differences up to 35–40 g/hr between individuals with the same BM). At present, the overall evidence does not support a change in the recommendations simply based on BM but highlights the fact that carbohydrate intake plans may have to be personalized according to various factors including gastrointestinal tolerance.

Despite the trends for very high carbohydrate intake as discussed above (120 g/hr and more), there is currently little or no scientific evidence to explore how intake >90 g/hr influence cycling performance. Findings from other endurance disciplines (mountain running) have suggested that a higher intake might reduce perception of effort or postexercise markers of muscle damage (Urdampilleta et al., 2020; Viribay et al., 2020); however whether this has any relevance to cycling is unknown due to the lack of specific research. Regardless, higher intake of carbohydrate during stage racing may not only provide a direct performance benefit but also contributes to maintaining overall energy balance goals (Table 1). It is also possible that, as long as the muscle carbohydrate stores are sufficient for the duration of race requirements, the suppression of fat oxidation might create a small but worthwhile increase in power outputs during high-intensity efforts close to critical power given the higher economy of energy production from carbohydrate oxidation (Burke et al., 2019, 2020; Burke, Ross, et al., 2017). One benefit of high carbohydrate intake on the bike is also that this carbohydrate will still be absorbed and will be available immediately after exercise, faster than any recovery meal that is ingested after the end of training or after crossing a finish line. In other words, the high carbohydrates can help to manage and optimize carbohydrate intake during the day. Studies should investigate the effects of high carbohydrate intake on the bike on recovery afterwards.

Managing Daily Carbohydrate Intake Within a Stage Race

As discussed earlier in this review, stage races challenge the rider to recover between a series of daily races of varying workloads and, sometimes, race formats (e.g., individual or team time trials). Previous practices heavily relied on the poststage period (and in the case of Grand Tours, two rest days interspersed within the 3 weeks of racing) to consume large amounts of carbohydrated and energy to allow the rider to keep pace with high overall needs. However, changes in knowledge and logistical support for teams within WorldTour ranks at least, has dramatically changed the culture and nutritional practices of stage racing over the past decade (personal observations, Redegeld, Martins, & Jeukendrup, 2025; Lis & Strobel, 2025). Personalized and periodized daily nutrition targets are set by a performance team including coaching staff, sports scientists, and nutritionists and delivered on the road by performance chefs, and soigneurs. In addition to setting and monitoring the achievement of carbohydrates and energy targets tailored to the specific stage characteristics and race roles of each rider, contemporary practice is to spread race nutrition more evenly over the day. This is made possible by increased on-bike intake, but also by catering in team buses that make use of transfer periods to and from race sites and hotels. Depending on the outstanding needs from the completed stage, and anticipated demands of the next day, appropriate amounts of carbohydrates, protein, fluid, and other nutrients will be provided at the postrace transfer (to maximize immediate recovery), at the evening meal and potentially, a prebed snack.

Hydration Recommendations

Fluids consumed during a road cycling race have the potential to: (1) address the fluid deficit that may be already present, or that is accrued during the event due to the evaporation of sweat as a key mechanism to dissipate heat and maintain body temperature within acceptable limits; (2) deliver energy, carbohydrate, or performance supplements (e.g., caffeine) that are part of the cyclist's race nutrition plan; and (3) relieve thirst sensation which could affect performance independent of dehydration. There is some controversy within sports nutrition regarding the effect of dehydration on performance as well as the need for athletes to drink to a plan during exercise. Indeed, a meta-analysis of laboratory-based cycling time-trial protocols reported that dehydration may not impair performance until the fluid deficit exceeds 4% BM and that drinking to thirst is sufficient to avoid significant dehydration (Goulet, 2011). Furthermore, it has been claimed that the available literature may inflate the true impairments caused by hypohydration, since: (1) many studies are open-label and susceptible to placebo bias; (2) many laboratory studies take absolute power as the outcome variable, when power to mass (i.e., power relative to BM, W/kg) may show attenuated decrements; and (3) laboratory conditions fail to mimic convective cooling in outdoor conditions (Dugas et al., 2009). However, this does not consider the issues in professional cycling where small margins in performance are important, and carry-over effects of increased effort across multiday events may be significant. Furthermore, laboratory-based time trials do not capture the cognitive component of cycling races, where rapid decision making may be required regarding making and/or covering attacks, navigating the peloton and responding to obstacles on the road (e.g., tight turns, pinch-points, barriers in the middle of the road, etc.). Tactical decisions (e.g., which moves to follow) are important. This cognitive component has not received considerable attention, even though it is generally acknowledged that some riders are better at "reading the race" than others, and these processes are also likely influenced by fatigue.

Real-life sport is complex, and decisions regarding fluid intake should be appraised according to a risk: benefit analysis that deals with specific sweat rates/fluid deficits (Ebert et al., 2007), the availability of fluids/drinking opportunities, and the likely outcomes caused by a lack of a fluid plan in a specific event (Burke et al., 2019). Practically, executing a detailed plan is logistically difficult given the varied access to fluids, and finding opportunities to drink. Moreover, the amount a rider consumed from a given bottle is inconsistent, and they are often discarded prior to receiving new ones making it impossible to accurately monitor intake. However, it is possible to give riders personal targets and to educate them to manage their hydration, and it is also possible to get a rough estimate of how effective their drinking was via assessing postrace BM.

Unfortunately, much of the commentary and the currently available guidelines regarding fluid intake during exercise are based on running (American College of Sports Medicine et al., 2007). The high sweat rates and "cost" of consuming fluids during hot weather marathons mean that the winners of world class running races can accrue losses of 5%–10% BM (used as a proxy for fluid deficits) over a race (Beis et al., 2012), while anecdotes of the top finishers being the most dehydrated are popularly promoted as evidence that hydration plans can be disregarded (Pitsiladis & Beis, 2012). Hydration levels in road cycling will be partly determined by a drinking plan but also by drink availability from carers and from the team car. Table 5 also summarizes key issues that contribute to the development and implementation of hydration plans in road races.

The literature on sodium requirements remains mixed. Early studies and field observations suggested that high sweat sodium losses increase sodium requirements (Racinais et al., 2023) and it is often claimed that aggressive sodium replacements strategies can prevent performance decrements and exercise associated muscle cramps (Bergeron, 1996, 2003; Levin, 1993). However, studies have not demonstrated performance benefits of sodium supplementation (Cosgrove & Black, 2013; Earhart et al., 2015; Hew-Butler et al., 2006; Twerenbold et al., 2003). More recent work including that of McCubbin et al. (McCubbin, 2021, 2023, 2025) challenged the traditional claims showing through modeling that sodium balance can be maintained across a wide range of intakes. Current evidence suggests that sodium needs are highly context specific and that sodium can be replenished *after* exercise in most conditions. Contrary to common belief, the need for sodium supplementation *during* exercise to prevent hyponatremia or prevent depletion of body sodium stores is not necessary and more dependent on high fluid intake rates rather than sweat sodium losses (McCubbin, 2025).

Sleep

Adequate amount and quality of sleep is increasingly recognized as an important determinant of performance (Halson, 2014). While there are some initial observations that multiingredient (tryptophan, glycine, magnesium, tart cherry, and L-theanine) can enhance some aspects of sleep duration and quality (Langan-Evans et al., 2023), there is still relatively little consistent evidence that nutritional interventions can directly enhance sleep quality. On the other hand, there are nutritional strategies that can clearly limit sleep duration and/or quality, most notably caffeine intake. Whereas modest doses of caffeine (100 mg; equivalent to ~1 regular coffee), do not appear to alter sleep quality when ingested 4 hr before bedtime, larger doses (400 mg) can negatively impact sleep quality even when ingested 12 hr before bedtime (Gardiner et al., 2025). This evidence is highly relevant to stage racing, since caffeine is commonly ingested toward the end of a stage to optimize performance within that stage. The potential for this to then negatively impact sleep quality needs to therefore be considered in the context of the requirements for the next day. Whether multiingredient supplements can offset the effects of caffeine intake on sleep quality and duration, currently remains unclear.

Training and Preparation

World Tour cyclists typically race 40–80 days each year. While 90–110 race days was previously a typical annual commitment (Jeukendrup, 2002), modern professional teams increasingly now prepare their riders for key events by periodizing recovery and targeted training within the annual calendar (instead of racing as much as possible). Cyclists spend more time at altitude than ever before, and have more time managing their BM and composition before major events. Altitude camps are an integral part of the preparation of riders in particular climbers and general classification riders. The longer stays at altitude require adjustments in nutrition intake (especially iron, fluid, and perhaps carbohydrates), which is discussed in more detail in a companion paper (Cheung et al., 2025). Given there are fewer race days compared with a couple of decades ago, and races are more carefully selected, and prepared for there is less need to be at race weight all the time and plans can be developed to target specific weights and body composition for certain parts of the season. This periodized approach is also the recommended approach (Stellingwerff et al., 2019). This does not mean that old methods and ideas are eradicated. They are still very much present in the sport and will need to be addressed with education.

Nutritional supplements can also form an important part of a cyclists' training and racing. As mentioned, a detailed review of sports supplements commonly used in cycling is available in a companion piece to this series (Whitfield et al., 2025) and is therefore not covered in detail here. In brief, there is consistent evidence to support the use of carbohydrates and caffeine supplementation for road cycling performance, in addition to sodium bicarbonate (especially for time trials). Despite reported use by some cyclists, there is currently no reliable evidence that nitrates, creatine, or exogenous ketone supplements can enhance performance in elite (i.e., Tier 4 and Tier 5) road cyclists.

Body Mass and Body Composition Management Throughout the Year

Power-to-mass ratio is an important performance indicator in road cycling particularly when activities involve climbing or acceleration. Cyclists therefore often strive for a low BM and high ratio of muscle to fat, maximizing the amount of mass that contributes to force production (Mujika et al., 2016). Even small BM reductions can meaningfully impact pace; a 1 kg reduction is estimated to save 1–2.5 s/km at a 5% or 10% gradient respectively, which may be critical in a closely matched race. Accordingly, elite road cyclists tend to be both light and lean, with eight-site skinfold thickness estimated to range from approximately 30–50 mm for elite riders (Kasper et al., 2021).

While the benefits of a high power to mass ratio are well-recognized, undue emphasis on the BM side of the equation can lead to negative health and performance consequences if it encourages engagement in prolonged calorie restriction leading to critically low-fat mass, or harmful weight-loss practices. Further insights on managing energy availability and body composition goals in cycling can be found in the companion review by Burke et al. (2025). A seasonal plan with realistic BM goals achieved with a modest energy deficit while maintaining adequate carbohydrate, protein, and micronutrient intakes can minimize the performance and health risks associated with weight loss.

Future Research

There are several areas that still require additional research and exploration. The emerging trend of super high exogenous carbohydrate intake (i.e., ≥120 g/hr) lacks robust scientific evidence to support universal application in cyclists with varying levels of experience/training. It is also unclear whether the benefits of such high intake rates are for performance itself, recovery, or a mixture of both. As a logical extension, exploration of individual oxidation rates with varying carbohydrate compositions, and the effects of sex, BM, gut training, and so on, warrants further research. Traditionally, it has been assumed that glycogen resynthesis during exercise is minimal—however this may not be the case in elite athletes during prolonged exercise when supported by high carbohydrate intake rates. Research on the application of supplements such as sodium bicarbonate in road cycling contexts is required, as there is a lack of studies investigating its potential in elevating bicarbonate levels after several hours of racing and the possible effects on performance in the deciding moments of a race. Finally, there are also bigger and more complex topics such as BM management and how to determine a healthy or an optimal BM/composition for a rider which require the integration of different disciplines including nutrition, physiology, and sports medicine.

Conclusions

Nutrition is increasingly recognized as a critical performance factor in road cycling. Key issues in single day and stage racing include managing glycogen stores before a race, postrace refueling, and strategies to address bike fuel and hydration requirements. Managing nutrient needs in a personalized and periodized manner is becoming commonplace, with nutritionists becoming a key and integrated part of the performance staff for professional cycling teams. The evolution of knowledge and practice continues within professional road cycling, with contemporary focus on the gradual increase of carbohydrate intake during races to support the high fuel and energy requirements of road events particularly during stage racing. Although management of BM/composition continues to be a highly topical theme in road cycling, the important message is that lower BM is not always better. Instead, BM management should be a careful process of realistic and healthy goal setting, periodized training and nutrition and a safe environment for riders. Among performance supplements, caffeine remains of interest, with newer developments in the area of sodium bicarbonate/buffering support. In contrast, other supplements like ketone esters and nitrates lack strong support for use in road cycling.

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Nontechnical Summary

Professional road cycling is an endurance sports characterized by diverse energetic demands. Races can last anywhere from a few minutes to more than 7 hr and may be contested over a single day or up to 3 weeks as is the case in Grand Tours. While much of a race is spent riding at relatively moderate intensities, the moments that dictate the winner—such as attacking on a climb, bridging to a breakaway, or sprinting for the finish—require very high power outputs. Nutrition plays a central role in enabling riders to meet these demands and has become a critical performance factor in modern professional cycling.

Over the past two decades, there has been a major increase in the speed of the peloton. Advances in sports science, combined with increased logistical support, have transformed race nutrition from a largely reactive practice into a highly planned, individualized, and performance-driven strategy. This review focuses on the fundamentals of energy and macronutrient metabolism in road cycling and highlights how nutritional practices—particularly carbohydrate intake—have evolved both on and off the bike to support the increasing intensity and tactical complexity of contemporary racing.