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Review Article

Effect of Carbohydrate, Protein and Their Combined Supplementations on Cycling Performance: A Brief Review

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Abstract

This review illustrates the impact of carbohydrate (CHO) and protein (PRO) supplementation on cycling performance. Strategic nutritional planning greatly benefits endurance athletes, particularly cyclists, as it underscores the critical role of macronutrient consumption in improving on the track/road performance and recovery. CHO is the primary energy source for prolonged cycling, as they are crucial for preserving optimal performance by preventing glycogen depletion and delaying fatigue. The efficacy of CHO is significantly influenced by their glycemic index (GI). High-GI CHO offers a rapid energy source that facilitates muscle glycogen resynthesis and sustained performance. Research suggests that high-GI CHO can increase muscle glycogen levels by up to 40% within four hours, underscoring their significance during and after pedaling.

PRO, although not the primary energy source, is essential for synthesizing and repairing muscles, particularly during prolonged and intensive cycling. Incorporating essential amino acids to facilitate recovery is imperative, as they aid in muscle protein synthesis and mitigate muscle fatigue. Recent studies have demonstrated that PRO supplements, especially after pedaling, significantly enhance muscle glycogen and protein synthesis replenishment, leading to quicker recovery and improved performance during cycling sessions.

The synergistic benefits of the combined supplementation of CHO and PRO are greater than those of each macronutrient alone. This combination improves endurance, delays fatigue, and ensures more efficient recovery by increasing glycogen storage, accelerating recovery, and enhancing muscle protein synthesis. The optimization of the benefits of these supplements is contingent upon the timing, dosage, and composition. Glycogen replenishment and muscle protein synthesis are optimized by consuming CHO and PRO immediately prior to and following exercise. This is particularly true for high-GI carbohydrates, such as glucose, and swiftly assimilated PRO, such as whey.

In conclusion, this review provides practical recommendations for cyclists seeking to optimize their nutritional strategies by synthesizing findings from various studies. Cyclists can enhance their overall performance and achieve long-term athletic success by developing effective dietary plans that improve endurance, defer fatigue, and facilitate efficient recovery, facilitated by understanding the complex interactions between these macronutrients.

Keywords:
Carbohydrate, Protein, Carbohydrate-Protein Ingestion, Cycling

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1. Introduction

Nutrition is essential to optimal performance and recovery in endurance sports, particularly for cyclists who require sustained energy output over extended periods. Cycling competitions vary significantly in distance and duration, ranging from short 200-meter sprints that last only 10 to 12 seconds to the demanding 5000-kilometer Tour de France, which spans 23 days (1-3). Extensive research has been conducted on the complex relationship between diet and athletic performance, resulting in significant insights into how specific nutrients (4), such as carbohydrates (CHO) (5) and proteins (PRO) (6), can improve endurance, defer fatigue, and facilitate recovery.

The primary energy source during prolonged exercise is CHO, which are essential for maintaining performance (5). During prolonged physical activity, muscle glycogen, a stored form of glucose, is depleted and thus a primary factor contributing to fatigue (7). Endurance athletes must consume sufficient CHO to maintain adequate glycogen stores (8). CHO supplementation before and during exercise has consistently revealed significant improvement in performance by regulating blood glucose levels and delaying the onset of fatigue (9). In cyclists, consuming high-glycemic index CHOs prior to pedaling has enhanced endurance performance by maintaining blood glucose for prolonged durations, thus providing a readily accessible energy source (10). The recovery process is more efficient when CHO is consumed immediately following exercise (11, 12).

Although PROs are not the primary energy source, they are essential for the repair and rehabilitation of muscles. Dietary PROs are required to facilitate regeneration and synthesis, as muscle PROs can be broken down during prolonged (6) and intense exercise (13, 14). PRO supplementation offers advantages that surpass muscle regeneration (6); they encompass improved recovery periods (15), reduced muscle soreness (16), and enhanced muscle PRO synthesis (17), all of which are indispensable for bikers who participate in rigorous training regimens (18). It has been demonstrated that cyclists can sustain high levels of performance over multiple training sessions by consuming PRO immediately after exercise, which assists in muscle regeneration, reduces soreness, and promotes overall recovery (19, 20).

The effects of combined CHO-PRO supplementation on cycling performance are an intriguing area of research (21-23). Studies have shown that the concurrent consumption of CHO and PRO can enhance the advantages of each macronutrient individually. The use of a combined CHO-PRO supplement has been shown to enhance muscle PRO synthesis (24), speed up recovery processes (25), and increase glycogen storage (26). These combined effects can result in prolonged pedaling, delayed fatigue, and more efficient recovery, potentially improving cyclists' performance.

Assessing the timing, dosage, and composition of dietary supplements is crucial for optimizing the benefits of CHO and PRO supplementation (27-29). Consuming CHOs and PROs before/during, and after cycling can optimize glycogen replenishment and muscle PRO synthesis. Furthermore, the type of CHO/PRO ingestion can impact the effectiveness of supplementation methods. The most practical advice for athletes is to develop supplementation programs customized to their unique training requirements, dietary preferences, and performance objectives pursuits (23, 30, 31). This review integrates insights from various research studies to illustrate how cyclists can maximize their nutritional strategies by incorporating CHOs and PROs. By comprehending the complex balance and interaction between these macronutrients, coaches and bikers can develop effective nutritional strategies that improve endurance, delay fatigue, and facilitate efficient recovery. This thorough examination of current research is intended to inform the development of evidence-based dietary strategies for endurance athletes, promoting the best sports nutrition practices for cycling performance.

2. Materials and Methods

This brief review evaluates well-documents dietary patterns to assess their impact on CHO and PRO utilization and their subsequent enhancement of athletic performance. This article focuses on a diverse array of CHO and PRO diets, although it only comprehensively examines some such diets. The primary sources for this analysis were peer-reviewed articles from PubMed, supplemented by studies from Google Scholar, Scopus, Ovid MEDLINE, OVID Healthstar, and the Cumulative Index to Nursing and Allied Health Literature (CINAHL). The search was conducted without regard to date and was concluded in 2024, ensuring the most up-to-date information. It included narrative and systematic reviews and meta-analyses that addressed dietary patterns' impact on athletic performance. The regimens that were examined were those that were most frequently cited in the scientific literature during this time. In order to substantiate the conclusions of this study, additional measures were implemented, such as an exhaustive examination of the primary studies referenced in these articles.

3. Carbohydrate Supplementation in Cycling

In cycling, the strategic consumption of macronutrients, particularly CHO (32) and PRO (33), are essential for improving endurance performance (34-36). CHO is the primary fuel source for both high-intensity and endurance activities, and they are essential for maintaining high levels of energy during protracted periods of cycling (37). The stomach can absorb CHO into the bloodstream without causing discomfort during pedaling. The type of CHO is essential for glycogen resynthesis, with higher glycemic index (GI) intakes being more effective (38, 39).

The GI is a metric that describes the rise in blood glucose levels due to consuming CHO, developed in 1980 at the University of Toronto (40). This scale quantifies the proportion of blood glucose produced in response to specific diets compared to glucose (41). Low-GI diets induce a gradual increase in glucose concentration, providing a balanced and sustained energy level, while high-GI diets induce a rapid increase (40). Blood glucose levels are rapidly elevated by high-GI diets, which are rapidly absorbed (42). Conversely, low-GI diets produce a gradual rise in blood glucose levels due to their slow absorption (42).

The digestion rate of a diet is influenced by the CHO type, fiber content, food form, and fat or PRO amount (43-45). Blood glucose and insulin levels are significantly raised by elevated glycemic loads (46-48). Due to their glycemic and insulinemic responses, high-GI diets (GI ≥ 70) increase muscle glycogen resynthesis rates and performance (49). Within four hours, the consumption of high-GI diets can elevate muscle glycogen levels by as much as 40% (50). High-GI diets provide athletes with a rapid energy boost during exercise (51), empowering them and making them feel energized. These diets are most effective when consumed during or after exercise, as they enter the bloodstream quickly (52). High-GI CHO supplements are appropriate for training due to their rapid increase in muscle glycogen (53, 54). CHO is typically consumed independently during training, with the exception of endurance training, where PRO may also be advantageous (55).

During cycling, various CHO types have a similar impact on metabolism and performance (5, 56, 57). Fructose (58) and galactose (59) oxidize at lower rates than glucose due to their conversion to glucose in the liver. This conversion can result in gastrointestinal distress and reduced performance (60). Glucose oxidizes at a rate of up to 1 $g.min^{-1}$, and the oxidation rates of CHOs are classified as either lower (0.6 $g.min^{-1}$) or higher (1.0 $g.min^{-1}$) (36). Due to its amylopectin-to-amylose ratio, insoluble starch undergoes oxidation at a slower rate (61). High amylopectin starches are rapidly absorbed, whereas high amylose starches hydrolyze slowly. The oxidation rate of amylose is low, while amylopectin is consistent with the high oxidation rate of glucose (60). Both solid and liquid CHO forms are effective during pedaling, eliciting comparable metabolic responses (62, 63). Nevertheless, liquid supplements are more convenient to consume during physical activity and mitigate the risk of dehydration (64). Solid supplements are more energy-dense, however, they may have a less significant impact on gastric emptying, particularly when combined with fibers or electrolytes (65).

The stomach can absorb CHO into the bloodstream without causing discomfort during cycling (66). Coyle et al. (2001) and Naderi et al. (2023) have demonstrated that the type of CHO consumed is essential for glycogen resynthesis, with higher GI intakes more effective (23, 38). After consuming CHO, the GI assesses the rise in blood glucose (40). The University of Toronto scientists established this metric in 1980 to quantify the proportion of blood glucose produced in response to specific diets compared to glucose (67). The glucose concentration increases gradually with low-GI diets, while it increases rapidly with high-GI diets (40). High-GI diets are rapidly absorbed and cause an increase in blood glucose levels (42). In contrast, low-GI diets gradually raise blood glucose levels due to their slow absorption (42, 68).

The rate of digestion of a diet is influenced by the CHO type, fiber content, food form, and fat or PRO amount (44, 45). The levels of blood glucose and insulin are significantly elevated by elevated glycemic loads (47, 48). As a result of their glycemic and insulinemic responses, high-GI diets (GI ≥ 70) are particularly beneficial for athletes, as they increase muscle glycogen resynthesis rates and performance (49, 63). According to Coyle et al. (1985), the consumption of high-GI diets can raise muscle glycogen levels by as much as 40% within a four-hour period, providing a rapid energy boost during exercise (50). This rapid energy boost is especially beneficial for athletes during exercise, which is achieved through the consumption of high-GI diets (51). According to Burke (1995), these diets are most effective when consumed during or after exercise, as they are rapidly absorbed into the bloodstream (52). Additionally, Kushnick et al. (2008) have suggested that high-GI CHO supplements are appropriate for training due to their rapid increase in muscle glycogen (54). In general, CHO is consumed independently during pedaling, with the exception of endurance cycling, where PRO may benefit (3, 69).

The metabolic and performance effects of various CHO types during cycling are comparable (5, 56, 57). The oxidation rates of different CHO types play a crucial role in their performance effects. Glucose undergoes oxidation at a rate of up to 1 $g.min^{-1}$, whereas fructose (58) and galactose (59) undergo oxidation at a slower rate as a result of their conversion to glucose in the liver. This conversion process has the potential to result in gastrointestinal distress and lower performance (60). As Saris et al. (1993) suggested, the ratio of amylopectin to amylose in insoluble starch leads to a slower oxidation rate (61). However, high amylopectin starches are quickly absorbed, while high amylose starches undergo slow hydrolysis. Amylose undergoes oxidation at a low rate, while amylopectin emulates the high oxidation rate of glucose (60). Solid and liquid CHO forms are both effective during cycling, eliciting comparable metabolic responses (62).

To achieve optimal cycling performance, consuming a sufficient amount of CHO to avoid gastrointestinal issues and maximize exogenous oxidation is crucial. Rehrer et al. (1992) conducted a study in which cyclists consumed glucose solutions at rates of 4.5% and 17% during 80-minute endurance trials (70). While the oxidation rate remained stable, the CHO oxidation rates significantly increased with higher dosages. Nevertheless, Murray et al. (1991) and Mitchell et al. (1989) conducted research that needed to establish a clear dose-response relationship between CHO intake during cycling and endurance performance (71, 72). After 120 minutes of cycling, Jeukendrup et al. (1999) observed that oxidation rates of up to 0.94 $g.min^{-1}$ were achieved when larger CHO amounts were consumed (73).

Burgess et al. (1991) discovered that consuming 13 $g.h^{-1}$ of CHO during endurance cycling at 70% VO_2max did not affect metabolic variables, RPE, glucoregulatory hormone response, or time-to-exhaustion (74). Similarly, Murray et al. (1991) found that 4.8 km endurance cycling was enhanced to comparable levels after 2 hours of pedaling at 65 to 75% VO_2peak when CHO intakes of 26 and 78 $g.h^{-1}$ were consumed (71). Casa et al. (2000) observed that increasing CHO intake did not result in improved exogenous glucose oxidation rates, suggesting that the beneficial impact of CHO supplementation is limited to intakes between 4% and 8% (75). CHO supplementation, particularly in the range of 30 to 60 $g.h^{-1}$, is effective in maintaining blood glucose levels without causing gastrointestinal distress or fluid delivery impairments. Thus, it helps in sustaining performance during endurance cycling. Bikers should consume fluids at a rate of 600 to 1200 mL per hour to prevent decreased performance due to dehydration (76, 77). The necessary fuel and hydration for endurance cycling can be achieved by ingesting 5 to 10 g of CHO per 100 mL for optimal cycling performance (78). Recent research indicates a curvilinear dose-response relationship between CHO supplementation and endurance exercise, with the best 20-km cycling time trial performance achieved at 78 $g.h^{-1}$ CHO (79-81).

4. Protein Supplementation in Cycling

PROs play a critical role in the body's ability to repair and rebuild muscle tissues, particularly following intense physical activity (19). For cyclists who often engage in prolonged and strenuous exercise, adequate PRO intake is essential for optimizing performance and recovery (82). In the human body, nine of the twenty amino acids required for bodily functions are not synthesized (83). These amino acids are as follows: phenylalanine, threonine, tryptophan, valine, methionine, histidine, isoleucine, leucine, and lysine. Cyclists must incorporate them into the diet plan to ensure they receive adequate essential amino acids. Valine, isoleucine, and leucine are the three Branched-chain amino acids vital for bioenergetics and cycling (18, 84). PRO consumption is crucial for the maintenance of health and the enhancement of cycling performance (85). The recommended daily PRO intake for adults is normally 0.8 $g.kg^{-1}$ of body weight (33). The recommended PRO intake for endurance athletes, including cyclists, ranges from 1.2 to 2.0 $g.kg^{-1}$ per day. This intake should be evenly distributed across meals to ensure a constant supply of amino acids for muscle repair and recovery (8, 20).

Research findings have been presented concerning the impact of PRO supplementation on physical activity, demonstrating its efficacy in enhancing the endurance performance of elite athletes (86). Supplementation with branched-chain amino acids during cycling has been demonstrated to augment performance by serving as an additional energy source, enhancing nervous system functionality, and mitigating excessive PRO catabolism (83, 87). It is a common practice to categorize types of PROs into complete and incomplete PROs based on their biological value (88). Animal-derived complete PROs are considered high-quality because they contain the nine essential amino acids in adequate quantities (89). Evidence suggests that plant-based PRO sources, such as vegetables, seeds, nuts, and legumes, have been erroneously labeled as low quality or incomplete due to their perceived inadequate supply of essential amino acids (90, 91). The PRO quality is enhanced by combining plant-based ingestions, adding milk products to a plant source, or mixing various plant sources (88). PROs facilitate muscle development through a fundamental process known as muscle PRO synthesis, in which leucine serves as a pivotal amino acid, initiating this physiological mechanism (19).

Numerous studies have highlighted the benefits of PRO supplementation for enhancing cycling performance and recovery (4, 16, 20). A study by Koopman et al. (2004) demonstrated that the ingestion of a CHO-PRO supplement post-exercise enhanced muscle glycogen resynthesis and increased PRO synthesis compared to CHO alone (92). Another study by Saunders et al. (2004) found that cyclists who consumed a CHO-PRO supplement experienced improved endurance performance and reduced muscle damage during prolonged cycling (31). These findings suggest that PRO supplementation not only aids in muscle repair and recovery but also contributes to better overall performance in endurance activities like cycling (85).

5. Combined Carbohydrate and Protein Supplementation for Cycling Performance

Combining CHO and PRO for supplementation has gained substantial attention due to the potential synergistic effects that enhance athletic performance, particularly in endurance sports such as cycling (18, 85, 93). The integration of these macronutrients supports sustained energy supply, muscle recovery, and overall performance improvement (94). Essential amino acids enhance insulin response to CHO, facilitate creatine consumption (95), and increase glycogen storage by supporting muscle synthesis (96). Enhanced muscle oxidative capacity is among the significant adaptations that transpire during cycling (97). Resistance training primarily results in muscle hypertrophy, whereas endurance cycling increases the size, number, and enzyme content of mitochondria, suggesting a disruption in amino acid metabolism (98, 99).

As mentioned, cycling performance can be improved by combining CHO with other macronutrients (30, 88, 100). Small quantities of CHO and PRO, such as 50 g of CHO and 5 to 10 g of PRO, consumed 30 to 60 minutes prior to and during cycling, can enhance CHO availability, enhance performance, and facilitate recovery (101, 102). Elevated nitrogen losses observed during cycling can be attributed to heightened PRO oxidation, thereby implicating the contingent nature of nitrogen balance on the cyclist's training status, quality and quantity of PRO intake, overall caloric consumption, body CHO reserves, and specific pedaling adaptations (60, 103). A 3-4:1 ratio of PRO to CHO improves endurance performance and expedites glycogen resynthesis during and after cycling (31, 92). As Ivy et al. (2002) demonstrated, adding 0.2 to 0.5 $g.kg^{-1}$ of PRO to CHO at a 3:1 ratio significantly enhances glycogen resynthesis (104). In another study, Ivy et al. (2003) conducted the first investigation to show improved performance in time-to-exhaustion through CHO-PRO ingestions in their laboratory (100). Their study investigated the effects of ingesting a 7.75% CHO solution, a 7.75% CHO with 1.94% PRO (CHO-PRO) solution, and placebo on endurance pedaling performance when administered at 20-min intervals (200 mL). They concluded that endurance cycling was significantly enhanced when PRO was added to a CHO supplement, as opposed to when CHO was used alone. Rather than the inclusion of PRO in the supplement, the improved performance was theoretically the consequence of a higher caloric intake of CHO–PRO. Martinez-Lagunas et al. (2010) investigated the impact of a placebo, a 4.5 %

CHO plus 1.15 % PRO drink, a 3 % CHO plus 0.75 % PRO drink, and a 6 % CHO drink on cycling performance at intensities for over 150 minutes until fatigue (105). This study concluded that the combined CHO-PRO supplementation could prove advantageous for sports beverages in endurance cycling while restricting caloric intake and CHO consumption.

Further research provides evidence that endurance performance is enhanced through the consumption of CHO-PRO combinations, as opposed to consuming CHOs alone (31, 106). Ferguson-Stegall et al. (2010) examined the impact of CHO-PRO supplementation on cycling performance (107). According to this evidence, endurance capacity can be enhanced by CHO-PRO supplements. Ghosh et al. (2010) used 60 g of sago-soy supplementations at 20-minute intervals during 60 minutes of cycling at 60% of VO_2max (21). The combined supplementations of soy PRO and sago CHO effectively delay fatigue during cycling. In contrast, some scientific sources indicate that the consumption of CHO-PRO has a diverse impact on cycling performance. Romano-Ely et al. (2006) compared the effects of a CHO-PRO supplement and an isocaloric CHO supplement on the time to fatigue (108). Their findings indicated no difference in the time to fatigue between the two trials when cycling. Van Essen and Gibala (2006) conducted a study to examine the impact of adding 2% PRO to a 6% CHO drink, in comparison to a 6% CHO drink and a placebo, during an 80-km cycling time trial, concluding that consuming CHO-PRO intake did not significantly improve cycling performance (109). A similar result was also seen in other studies (22, 110, 111).

6. Practical Recommendations for Cyclists

For competitive cyclists, the optimal balance of CHO and PRO in their diets is crucial for recovery and performance (93, 112). A 3:1 or 4:1 ratio of CHO to PRO is often recommended to meet the high demands of cycling, aiding in glycogen replenishment and muscle repair (113). Adjusting this balance based on the duration and intensity of cycling activities can significantly improve energy storage and muscle recovery. For instance, consuming a meal high in CHO and moderate in PRO, such as a whole-grain sandwich with lean meat or oatmeal with fruit and yogurt, three to four hours before pedaling can boost energy levels. Additionally, a recovery shake with around 60g of CHO and 15-20g of PRO taken within 30 minutes of riding can help rapidly replenish glycogen and aid in muscle tissue regeneration.

This dietary approach can be tailored to the specific needs of individual cyclists by considering their genetic background, training status, and dietary preferences, all of which affect nutrient metabolism and diet effectiveness (Table 1). Therefore, personalized nutrition plans should be developed through trial and error, observing the impact of different food sources on recovery and performance. Unique dietary options, like vegan or gluten-free, should also be provided to meet nutritional requirements without compromising digestive health (114). When riding in hot and humid situations, it is crucial to maintain an adequate electrolyte balance and prevent dehydration (22). Athletes should ensure adequate hydration, particularly with electrolyte-rich fluids, and consider using dietary supplements like PRO powders and CHO gels to complement their diet. However, whole foods should always remain the primary source of nutrition. Ultimately, adhering to a strategic and personalized dietary plan based on scientific knowledge and continual monitoring will help athletes achieve their long-term athletic goals and optimal performance (115).

Table 1. Overview of Practical Recommendations for Cyclists.

Stage/Category	Timing	Dietary Composition	Examples
Pre-Exercise Intake	3-4 hours before cycling	High in CHO (1-2 g.kg^{-1} body weight), moderate in PRO (0.3 g.kg^{-1} body weight)	Oatmeal with fruit and yogurt, whole grain sandwich with lean meat
Intra-Exercise Intake	For cycling sessions longer than 60 minutes	30-60 g of CHO per hour, small amounts of PRO (5-10 g)	Sports drinks, CHO gels
Post-Exercise Intake	Within 30 minutes after cycling	A 3:1 CHO to PRO ratio; about 1-1.2 g.kg^{-1} of CHO and 0.3 g.kg^{-1} of PRO	Chocolate milk, PRO shakes with fruit, banana with nut butter
Personalization of Nutrition	-	Trial and error to find the best CHO and PRO sources	As mentioned above.
Special Diet Plans	-	Vegan or Vegetarian: Focus on plant-based PRO such as legumes, quinoa, nuts	As mentioned above.
Hydration	-	Emphasis on adequate hydration alongside electrolyte-rich fluids	-
Supplementation	-	PRO powders (whey, plant-based), CHO gels, sports drinks	As mentioned above.

7. Conclusion

In conclusion, the performance of cyclists, particularly in endurance events, is substantially influenced by the complex relationship between CHO and PRO supplementation. The optimization of performance and recovery is contingent upon understanding the metabolic demands and the role of macronutrients during prolonged cycling.

According to extensive research, the strategic consumption of CHO and PRO before, during, and following cycling can significantly improve endurance pedaling, delay fatigue, and accelerate recovery. The primary source of sustenance for high-intensity and endurance cycling is CHO, and the effectiveness of the consumed CHO is significantly influenced by its GI. During cycling, high-GI CHO is rapidly absorbed, leading to a quick rise in blood glucose levels. This substance's rapid absorption facilitates muscle glycogen's resynthesis, which plays a crucial role in maintaining sustained performance during prolonged cycling sessions. Research has shown that high-GI CHO can increase muscle glycogen content by up to 40% within four hours of consumption, enhancing performance by providing readily available energy. In addition to boosting CHO oxidation rates, the consumption of a combination of glucose and fructose can also enhance overall endurance.

PRO, while not the primary energy source, plays an essential role in the repair and rehabilitation of muscles. Branched-chain amino acids, as essential amino acids, significantly contribute to muscle PRO synthesis, alleviate muscle soreness, and promote expedited recovery. Research has demonstrated that promptly supplementing with PROs following exercise can substantially increase muscle glycogen resynthesis and PRO synthesis, resulting in improved recovery and sustained performance during subsequent training sessions. The study has demonstrated that adding PRO to CHO at a 3:1 ratio notably improves endurance performance and facilitates recovery. Another crucial factor is the timing of nutrient consumption. Consuming CHO and PRO at specific intervals before, during, and after exercise is key to maximizing their benefits. For instance, consuming CHO 30 to 60 minutes before cycling can raise blood glucose levels, providing an immediate energy boost. Maintaining a consistent intake of CHO is essential to maintaining energy levels and delaying fatigue during pedaling. After cycling, a combination of CHO and PRO can speed up recovery by replenishing glycogen stores and repairing muscle tissues.

It is imperative to develop customized diet plans to meet each cyclist's specific requirements, including training regimens, performance objectives, and goals. The cycling event's duration and intensity, individual metabolic responses, and dietary preferences must all be considered. During prolonged cycling sessions, riders should ingest 30 to 60 grams of CHO per hour and maintain proper hydration to achieve optimal performance. To maintain a consistent supply of amino acids for muscle repair and recovery, it is recommended that the daily PRO intake be adjusted to a range of 1.2 to 2.0 grams per kilogram of body weight, with even distribution across meals.

The synergistic effects of combined CHO and PRO supplementation are well-documented, and they offer substantial advantages in cycling recovery and performance enhancement. Cyclists can efficiently recover, maintain high-performance levels, and achieve their athletic objectives by adopting a strategic nutritional approach that considers CHO and PRO intake's type, timing, and quantity. This holistic understanding of sports nutrition is contingent upon developing effective dietary strategies that promote long-term athletic success.

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