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Review Article

Nutrition Section

# A Narrative Review on Nutritional Strategies for Ultra-endurance Cyclists: Emphasising Requirements for Brevet de Randonneurs Events in India

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## ABSTRACT

Ultra-endurance cycling, particularly in events such as the Brevet de Randonneurs Mondiaux (BRMs), demands exceptional physical exertion and sustained energy management. In India, BRMs events, which span distances of 200 to 1000 kilometres, pose unique challenges for cyclists, necessitating prolonged physical preparation and consistent performance under demanding conditions. Nutrition plays a critical role in optimising energy availability, enhancing recovery and sustaining performance throughout these events. Despite the wealth of information available through social media, there remains a significant gap in scientifically grounded nutritional guidance specifically tailored to ultra-endurance cyclists. The aim of the present narrative review is to highlight the critical nutritional requirements and strategies essential for ultra-endurance cyclists participating in BRMs events. The review emphasises the need for evidence-based dietary practices to support optimal performance and recovery while addressing the current gap in scientific understanding. It also provides practical, research-informed nutritional guidance for athletes involved in these ultra-endurance events. Pre-event preparation focuses on carbohydrate loading, hydration and balanced nutrition to maximise glycogen stores and ensure optimal hydration. During the event, continuous carbohydrate intake, electrolyte replenishment and hydration are critical for maintaining energy levels and preventing dehydration. Post-event recovery emphasises protein consumption for muscle repair, glycogen replenishment and rehydration. The findings underscore the importance of tailored nutritional strategies for ultra-endurance cyclists to achieve optimal performance and recovery. Despite the abundance of general information available, there is a clear need for more research-based, practical nutritional guidelines specifically for ultra-endurance cycling. Future research should address this gap to provide athletes with evidence-based recommendations that support their unique nutritional needs.


**Keywords:** Brevets de randonneurs mondiaux, Carbohydrate loading, Ultra-endurance cycling

## INTRODUCTION

Cycling is a sport characterised by high training volumes, a long-lasting season and a high level of competition. In India, interest in ultra-endurance cycling has increased dramatically in recent years. The World Ultra Cycling Association (WUCA) defines ultracycling as "any bicycle ride that is more than 200 kilometres in distance or six hours in duration, completed as a single effort." The Union Cycliste Internationale provides regulations and rider licenses [1].

Recently, BRMs have gained popularity, leading to significant participation in these cycling events. BRMs are endurance events that include long-distance cycling of 200, 300, 400, 600 and 1000 kilometres. Cyclists who complete these events in one calendar year are designated as Super Randonneurs by Audax India Randonneurs [2].

Ultra-endurance cycling encompasses both single- and multi-day events over set stages or timeframes. One of the most notable and challenging cycling events is the Race Across America (RAAM), which covers a distance of 4800 kilometres with an elevation gain of approximately 53 kilometres, to be completed in 10 days with no official rest stations or breaks. Another significant event is the Tour de France, where athletes must cover a distance of 3500 kilometres with an elevation gain of 48 kilometres spanning 21 stages over 23 days [2].

All these ultra cycling performances require proper nutrition to enhance the athlete's ability to train at their full potential. Ultra cycling events often lead to a significant energy deficit due to their long duration [3]. Early experiments, as far back as 1939, conducted by renowned scientists Christensen EH and Hansen O reported the impact of diet on cycling performance using static bicycles in a laboratory setting. The study highlighted the importance of carbohydrate intake during and after cycling events [4]. Cycling is the sport that has reported the highest calorie deficit alongside maximum energy expenditure [5]. It has been reported that during the Tour de France, energy expenditure can reach up to 8300 kcal per day for every 300 kilometres. To put this in perspective, the UK Dietary Reference Values (DRVs) estimate the daily energy requirement for men at 2,550 kcal and for women at 1,940 kcal [6].

**Energy systems utilised during cycling:** Cycling engages the major muscles of the body. Muscle activity is fueled by Adenosine Triphosphate (ATP), which is produced by the body in three ways:

a. The Phosphagen Energy System provides energy during climbs. Muscles can store a small quantity of creatine phosphate, which is used for high-intensity cycling lasting up to ten seconds.
b. The anaerobic glycolytic system breaks down muscle glycogen into ATP and lactic acid, supporting high-intensity cycling lasting for 2-3 minutes.
c. The aerobic system utilises oxygen to produce ATP from carbohydrates and fats. This system can provide energy for several minutes to several hours [7-10].

**Earlier work done on sports nutrition for trained cyclists:** Early experiments by Christensen EH and Hansen O (1939) investigated the effect of diet on the performance of cyclists using stationary bicycles in the laboratory. The key findings of the study highlighted the importance of carbohydrates in enhancing performance concerning intensity and duration [4].

A study by Bergström J et al., conducted quadriceps femoris muscle biopsies on nine subjects to investigate muscle glycogen levels in relation to the effects of low (protein and fats), medium (mixed) and high-carbohydrate diets on time to exhaustion. The subjects pedaled on a bicycle ergometer at a workload corresponding to 75% of their oxygen uptake until complete exhaustion. The average time to exhaustion was 59 minutes for the protein and fat diet, 126 minutes for the mixed diet and 189 minutes for the carbohydrate-rich diet. The key finding of the study was that a high-carbohydrate diet resulted in better performance and higher muscle glycogen levels. The study demonstrated that muscle glycogen is beneficial for the capacity to perform endurance sports for longer durations [11].

In 2005, Hansen AK et al., conducted a study on the mitochondrial marker, citrate synthase activity. The study reported that training with lower muscle glycogen improved citrate synthase activity, which in turn enhanced exercise capacity and delayed fatigue [12].

In 1986, Coyle EF et al., conducted a study on seven endurance-trained cyclists to determine the utilisation of muscle glycogen during strenuous exercise and the postponement of fatigue after feeding athletes high-carbohydrate solutions. The enrolled endurance cyclists exercised at 71±1% of Volume of Oxygen ($VO_2$) max until completion of exhaustion. There were two trials: the first was the placebo group, in which fatigue started after 3.02±0.9 hours of exercise, accompanied by a decline in plasma glucose of 2.5±0.5 mm and a decrease in the respiratory exchange ratio from 0.85 to 0.80. Muscle glycogen in the placebo group declined at an average rate of 51.4±5.4 mmol GU/kg/hour during the first two hours of exercise and decreased at an even slower rate of 23.0±14.3 mmol GU/kg/hour during the third and fourth hours. In contrast, in the trial group, individuals were fed carbohydrates and maintained plasma glucose levels for an additional hour before experiencing fatigue. However, the pattern of muscle glycogen utilisation was the same for both groups. The key finding of the study was that the intake of carbohydrates during prolonged strenuous exercise slowed the depletion of muscle glycogen and thus delayed the onset of fatigue. The athletes were oxidising carbohydrates at relatively high rates from sources other than muscle glycogen during the latter stages of prolonged strenuous exercise, which contributed to postponing fatigue [13].

A similar finding has been reported, namely, that there are comparable rates of muscle glycogen utilisation during prolonged cycling exercise [14-16]. A study by Tarnopolsky LJ et al., examined the abilities of 15 similarly trained endurance athletes (7 male athletes and 8 female athletes) to increase muscle glycogen concentration through carbohydrate loading for four days, resulting in carbohydrate intake levels ranging from 50-60% to 75% [14]. The study also evaluated gender differences in metabolism during submaximal endurance cycling at 75% of $VO_2$ max for 60 minutes. The findings indicated an increased muscle glycogen concentration of 41% and an improvement in performance time during the 85% of $VO_2$ max peak trial for men, whereas women did not show any increase in muscle glycogen concentration or performance time. It was noted that women rely more on lipid oxidation than carbohydrate oxidation compared to men.

In contrast, a study by Roepstorff C et al., reported no significant differences between the two genders regarding the relative utilisation of carbohydrates and lipids during oxidative metabolism when performing submaximal exercises [15]. Similar findings were reported in a study conducted by Zehnder M et al., which evaluated gender-specific usage of intramyocellular lipids and glycogen during exercise in nine male and nine female athletes. Measurements were taken before, during and after exercising on a bicycle ergometer at maximal workload for 3 hours [16]. Intramyocellular lipids and muscle glycogen levels were determined using magnetic resonance spectroscopy. $VO_2$ max and $CO_2$ production were measured with an open-circuit spirometer, which was subsequently used to calculate total fat and carbohydrate oxidation. The key findings of this study indicated that average fat oxidation was similar in both genders, while males exhibited significantly higher utilisation of carbohydrates as substrates for oxidation. Both genders demonstrated comparable values for total energy utilisation, glycogen storage and glycogen utilisation [16].

On the contrary, a study conducted by Hansen AK et al., demonstrated the effects of high and low muscle glycogen content during training [12]. This study involved seven untrained individuals who were asked to perform knee extensor exercises, with one leg trained under a low glycogen protocol and the other leg trained under a high glycogen protocol. Both limbs performed identical work, but one limb completed 50% of the training (i.e., every second session) with reduced muscle glycogen. Training with lower muscle glycogen improved exercise capacity and citrate synthase activity. Additionally, low muscle glycogen was associated with enhanced transcription of several genes, which contributed to improved training adaptation. This finding contradicted earlier studies that linked increased carbohydrate intake to improved performance, thereby introducing the concept of periodisation nutrition during training sessions [12].

A study by Yeo WK et al., investigated the effects of a cycle training program on endurance-trained cyclists, in which certain sessions were performed with low muscle glycogen content to assess training and performance. Two groups were formed: the first group received a high amount of carbohydrates, while the second group was provided with a low amount of carbohydrates. Muscle biopsies were taken before the training and rates of substrate oxidation were determined. The study found that resting muscle glycogen concentration, rates of whole-body fat oxidation, citrate synthase activity, beta-hydroxyacyl-CoA-dehydrogenase levels and the total protein content of cytochrome c oxidase subunit IV increased only in the first group that consumed low carbohydrates. Interestingly, both groups experienced an improvement in cycling performance of 10% [17].

Impey SG et al., published a theoretical framework for carbohydrate periodisation and the glycogen threshold hypothesis in 2018. They posited that exercise performance can be improved with periodic endurance training sessions that involve reduced carbohydrate availability. This may occur due to the activation of acute cell signaling pathways, which further promote training-induced oxidative adaptations in skeletal muscle, ultimately enhancing exercise performance [18].

Similar findings have been reported: a low-carbohydrate diet can lead to increased phosphorylation and enhanced gene transcription [19,20].

A study conducted on eight well-trained cyclists examined the effects of fat adaptation and carbohydrate restoration on metabolism and performance during cycling. The study concluded that participants exposed to a high-fat diet exhibited metabolic adaptations even after the restoration of carbohydrates.

Additionally, several studies have reported the benefits of ingesting glucose along with fructose during exercise, which results in enhanced carbohydrate oxidation compared to the ingestion of glucose alone. A carbohydrate beverage containing both glucose and fructose has been shown to improve 100 km cycling performance compared with an isocaloric glucose-only beverage [20-22].

**Nutrients requirement for cyclist:**

**I. Macronutrients:**

1. Carbohydrates are the body's preferred source of fuel and are stored in the body in the form of glycogen. A gram of

carbohydrate yields 4 kcal. The average glycogen content found in muscle is 500 g/mL, while in the liver, it is 80 g/mL. This can be influenced by various factors, including an athlete's body composition and training status [22-24]. Carbohydrates are a short-lived fuel source, so they require constant replenishment. Therefore, it has become extremely important to periodise carbohydrate intake before, during and after training sessions for better recovery and enhanced performance. On average, studies have reported that 6-12 g/kg of body weight is required for athletes. Additionally, sprint cycling is a very high-intensity and short-duration event that requires a carbohydrate intake of 6-8 g/kg of body weight per day, which would be approximately 65% of the total calorie intake. Distance cyclists need a greater carbohydrate intake of 8-10 g/kg of body weight per day, with a significant amount needing to be consumed during cycling. Therefore, cyclists must acquire the skill of eating on the bike [24,25].

2. Protein performs vital structural functions in the body and can be found in muscle, bone, cartilage, tendons, ligaments, skin and hair. Proteins are important for the repair, recovery and synthesis of cells. One gram of protein provides 4 kcal of energy. Proteins are made up of amino acids, which are categorised into essential and non essential amino acids [24-25]. The following guidelines have been provided by the International Society of Sports Nutrition regarding the intake of protein for healthy, exercising individuals. Based on the current available literature, the position of the society is as follows [26,27]:
   - Muscle protein synthesis is stimulated by resistance exercises and protein ingestion. The synergistic effect can be observed with protein intake before or after resistance exercises.
   - Daily protein intake can range from 1.4 to 2.0 g/kg of body weight per day (g/kg/d) for individuals focused on muscle building and exercise.
   - To improve lean body mass, high protein intakes of about 2.3 to 3.1 g/kg/d can be considered during hypocaloric periods.
   - Age and exercise regimen need to be considered before making protein recommendations and protein ingestion should be evenly distributed over 3-4 hours throughout the day.
   - Protein recommendations can also include 700-3000 mg of leucine as part of a balanced array of essential amino acids [26,27].

3. Fat is an essential nutrient and an important source of energy. The understanding of the role of dietary fats has significantly changed over the years. Fats are known to be reservoirs of energy, with 1 gram of fat yielding 9 kilocalories (kcal) of energy [28]. They are stored in adipose tissue and muscles as triglycerides and their breakdown leads to the availability of fatty acids and glycerol, which are metabolised in muscle cells to ultimately provide energy.

   Adopting a low-carbohydrate, high-fat dietary approach may offer endurance athletes an advantage in enhancing training adaptations for aerobic capacity [29]. Monounsaturated fatty acids and omega-3 fatty acids possess anti-inflammatory properties that can significantly aid in an athlete's recovery [30]. Studies on lipid supplementation have investigated fat oxidation during exercise and its impact on cycling performance. Research has reported decreased oxidation of muscle glycogen when cyclists were assigned a high-fat isocaloric diet, which explains the preference for fats over carbohydrates among endurance cyclists [31,32].

4. Dietary fibre is crucial for maintaining overall health, including digestive function, blood sugar regulation and cholesterol levels. For athletes, including cyclists, dietary fibre plays an essential role in optimising energy levels and digestive health. There are two primary types of dietary fibre:

- **Soluble fibre:** Found in fruits, vegetables, oats and legumes, this type of fibre dissolves in water and forms a gel-like substance in the intestines. It helps slow digestion, stabilises blood sugar levels and lowers cholesterol.
- **Insoluble fibre:** Found in whole grains, cereals and some vegetables, insoluble fibre adds bulk to the stool and promotes regular movement of waste through the digestive system, preventing constipation.

   Low dietary fibre intake, especially among athletes such as recreational cyclists, can negatively impact both health and performance. A lack of fibre can lead to gastrointestinal issues, poor nutrient absorption and reduced energy stability. For cyclists, who require consistent energy release during long training sessions or races, a low-fibre diet might lead to fatigue or digestive discomfort. Moreover, fibre helps support gut health, which is essential for immune function and overall endurance performance [33,34].

**II. Micronutrients:**

1. Vitamins and minerals: A varied diet that includes nutrient-dense food options and aims to meet energy demands always ensures an adequate spread of micronutrients, including vitamins, minerals and antioxidants. The requirements for vitamins and minerals are higher compared to a population of the same age and gender. Therefore, consuming a diet that incorporates all food groups throughout the day becomes even more significant in light of performance training. It is suggested to get tested for certain vitamins, such as Vitamin D, B12 and Folic Acid, as well as minerals like Iron, Calcium, Magnesium, Zinc, Phosphorous, Sodium Chloride (NaCl), Potassium, Copper, Selenium, Fluoride, Iodine, Manganese, Chromium and Sulphur, quarterly or biannually. Minerals are involved in almost all metabolic and physiological processes of the body, including muscle contraction and relaxation, enzyme activities, immune functions, antioxidant mechanisms and acid-base balance. Athletes who follow a calorie-restricted diet (typically one that is significantly low in calories for goals such as body composition changes) or who do not include items from food groups such as vegetables, fruits, dals, legumes, pulses, fibre-rich grains, mixed nuts and seeds, lean meat and fish and dairy may not meet their requirements. A colourful diet, often referred to as a rainbow diet, made up of fruits and vegetables, is the key to obtaining all necessary micronutrients and even phytochemicals, which are compounds in foods that exhibit anti-inflammatory and antioxidant properties [35,36].

2. Antioxidants: The higher intensity and volume of training, along with frequent competitions and additional stressors such as travel, lack of sleep and poor environmental adaptations, can lead to physiological, metabolic and psychological stress. These factors often result in an increased formation of compounds known as free radicals. Once these free radicals reach a certain threshold, they can cause oxidative stress and inflammation, potentially affecting an athlete's recovery. Antioxidants, such as vitamins A, C and E, play a crucial role as immune nutrients and can speed up the recovery rate. However, excessive doses of antioxidants can become counterproductive by reducing specific training adaptations [37,38].

3. Supplements: The World Anti-doping Agency (WADA) guidelines are noteworthy and are backed by high-quality

evidence to legitimise the use of supplements in many countries, including India [39]. Supplements, as their name suggests, are meant to supplement or support the existing diet; they are not intended to replace any aspect of it. The use of the right supplement at the right time and in the right quantity may create a small but significant difference in an athlete's performance. This could be due to its role in making more fuel available during training, enhancing recovery between sessions, improving certain adaptations to training, modifying body composition, or ensuring good health through the prevention or treatment of certain micronutrient deficiencies. In track and field, only five ergogenic (performance-enhancing) supplements have been confirmed to be effective. These include creatine, caffeine, nitrates, beta-alanine and sodium bicarbonate/citrate, along with sports foods such as proteins, sports drinks, sports gels and electrolyte drinks [39,41].

4. Hydration: It is an important aspect of an athlete's diet plan. Just as much effort is put into building a nutrition strategy or diet plan, similar effort should be devoted to creating a hydration strategy for training and competition. Dehydration of more than 2% of body weight can lead to poor motor coordination, physiological strain and negatively affect performance. Optimum athletic performance depends on the hydration status of athletes. Proper hydration strategies are crucial to prevent dehydration, maintain cardiovascular function and support thermoregulation. Inadequate hydration can lead to decreased athletic performance during training and at competitive events. A personalised hydration strategy should be developed, taking into account training loads, individual needs and external temperatures [42-46].

**Periodised nutrition for cyclists:** A long-term progressive approach designed to enhance athletic performance by varying training throughout the year is termed periodisation. It includes macrocycles (months- pre-competition phase), mesocycles (weeks- 3 to 5 weeks of cycles with 1 to 2 weeks of recovery) and microcycles (days- 1-week cycles). These training units are structured throughout the year to help athletes achieve the desired readiness to perform at their peak during targeted competitions [42].

The diversity in bioenergetics and biochemical demands of different track and field events makes this sport particularly suited for the implementation of periodised nutrition, which involves the planned, purposeful and strategic use of specific nutritional interventions to enhance adaptations targeted by individual exercise sessions or periodic training plans [Table/Fig-1].

**Nutritional deficiencies and risk of sports injuries among cyclists:** Cycling is a gravitational sport and the low body weight of cyclists provides an additional benefit to their performance. Endurance cyclists need to maintain their body weight while preserving good lean muscle mass. Restricted nutrition can lead to Low Energy Availability (LEA), which has adverse effects on performance and can result in Relative Energy Deficiency in Sport (RED-S) [42]. Road cyclists are at a potentially high-risk of LEA due to long training sessions and increased energy expenditure. On average, a cyclist expends between 1,000 and 4,500 kcal during a single training session or event and if post-event energy demands are not met, the cyclist may remain in a state of LEA. Many athletes also choose to limit their energy intake to reduce body fat in order to maximise their performance, which can unintentionally lead them into a state of LEA and its consequences [33,42].

Energy availability significantly influences bone metabolism. The female athlete triad has been well described, highlighting the interrelationships between energy availability, bone health and reproductive function. Recent studies extend this concept to male athletes as "RED-S" [47-49]. It has been suggested that non-weight-bearing sport athletes (such as cyclists) are more susceptible to challenges in energy status than runners [50-52].

The LEA can lead to both short- and long-term consequences for the bone health of cyclists. Cyclists may develop impaired bone health, resulting in decreased osteogenic activity and an increased risk of fractures. A recent study by Keay N et al., examined the effects of a 6-month nutritional education intervention on 50 competitive cyclists who were at risk of RED-S [50]. The cyclists were paired based on Z-scores for lumbar spine Bone Mineral Density (BMD) and the results indicated that the control group experienced a 2.3% reduction in lumbar BMD between scans over the 6-month interval. In contrast, those who received nutritional education reported a 2.2% increase in lumbar BMD after six months. The findings of this study suggest a potential link between the nutritional knowledge of cyclists and lumbar BMD, which is likely influenced by energy availability. While this study offers useful insights into a strategy for improving knowledge, further research is needed to reinforce the association between nutritional knowledge and LEA [50]. A study by Mathis SL et al., on competitive male cyclists found a significant increase in lumbar spine BMD with resistance training. This finding emphasises the need to address LEA in RED-S and to prioritise the bone health of cyclists performing off-bike resistance training [51]. Studies have reported improved bone health with increased energy availability. Additionally, these studies have shed light on vitamin D levels. Increased vitamin D levels suppress the activity of parathyroid hormone, thereby decreasing bone resorption, in addition to improving immune functions and muscle strength [51].

Male cyclists with long-term LEA experience considerable effects on bone and endocrine health. Low BMD has been well-documented in athletes with LEA [53,54]. The lumbar spine is the most affected site, with the neck of the femur being a close second. The lumbar spine is trabecularly rich and has the least osteogenic properties, which explains its common susceptibility [54]. Female athletes with LEA often experience menstrual irregularities, whereas males may experience a decrease in testosterone levels and bone turnover

| Macro cycle | General preparation | Specific preparation | Pre-competition | Competition |
|---|---|---|---|---|
| Key nutrition challenges/ goals [42] | Body composition modifications, aerobic endurance (Fat adaptation) | Power- body weight ration substrate availability recovery | Substrate availability<br>recovery<br>race day strategy | Recovery<br>implementation of race day strategy |
| Nutrient recommendation [22,42] | Carbohydrates (CHO): 7-10 gm/kh body weight<br>Proteins: 1-2-1.7 gms/kg/bw/day<br>Fats: 1-1.2 gms/kg/bw/day | CHO: 9-12 gm/kh body weight<br>Proteins: 1.5-1.6 gms/kg/bw/day<br>Fats: 1-1.2 gms/kg/bw/day | CHO: 7-10 gm/kh body weight<br>Proteins: 1.6 to 1.7 gms/kg/bw/day<br>Fats: 1-1.2 gms/kg/bw/day | CHO: 7-8 gm/kh body weight<br>Proteins: 1.6-1.7 gms/kg/bw/day<br>Fats: 0.8-1.0 gms/kg/bw/day |
| Functional food and supplement strategies [42] | Sports drink<br>electrolyte drink<br>BCAA<br>L Cartinine<br>Iron rich food sources<br>Vit B112 folate rich sources<br>Nitrate Sources, multivitamins, fish oil, Vitamin C, Zinc, Magnesium | | | |

**[Table/Fig-1]:** Sample periodised nutrition plan for 200 km event.
CHO: Carbohydrates

markers [54]. Since testosterone is required for bone mineralisation and inhibits bone resorption, athletes with low testosterone levels are at risk of developing osteoporosis and are more susceptible to bone stress injuries. Calcium loss through sweating in elite cyclists (up to 150 mg/h) also negatively affects BMD [54].

Energy availability influences bone metabolism. The female athlete triad has been well described, emphasising the interrelationships between energy availability, bone health and reproductive function. There is a substantial amount of literature suggesting that LEA increases the risk of fractures; however, data indicates that post-traumatic fractures are more common among cyclists compared to stress fractures [47-55].

## CONCLUSION(S)

The present paper emphasises the need for both macro- and micronutrients required for training, muscle recovery and repair among ultra-endurance cyclists. Effective nutritional strategies are crucial for these athletes, particularly in the context of BRMs events in India, where optimising performance and recovery is paramount. The unique demands of long-distance cycling necessitate a tailored approach that emphasises proper macronutrient distribution, hydration and micronutrient sufficiency, while also addressing the risks associated with LEA, such as reduced BMD and hormonal imbalances. Both male and female athletes face distinct challenges, highlighting the need for targeted educational interventions to enhance nutritional knowledge. As research continues to evolve, it is vital to focus on evidence-based guidelines that support the health and performance of cyclists, ensuring they can compete effectively and sustainably in this demanding sport.

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