HIGHNORTH

Optimal Cycling Nutrition

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Introduction

Thanks very much for buying our cycling nutrition guide. We really hope you find it useful!

The purpose of this guide is to provide the fundamental theory and evidence-based principles needed to optimise nutrition, with the ultimate goal of supporting training, enhancing adaptations and improving performance. We try to convey this information in a practical and concise way, without scrimping on the important details.

This guide is not a recipe book or set of meal plans. Instead, the intention is to provide the tools and knowledge you need to manage your own nutrition, irrespective of your dietary preferences.

There's a glossary of key terms available within the supplementary materials of this guide, which might be useful if you've missed the definition for a particular term.

We also wanted to define some key cycling terms here, as we'll refer to these at several points in the guide.

- **Functional Threshold Power (FTP)**: This is the maximum power that can be sustained for approximately 40-60 minutes.
- **Lactate**: This is a molecule that's produced when carbohydrates are broken down to provide energy. Lactate itself is very useful, because it provides a portable source of energy. However, its presence also correlates closely with the presence of other metabolites that have been linked with fatigue.
- **Lactate Threshold**: This is the maximum power at which lactate levels in the blood remain constant. It's very closely related to FTP, but isn't exactly the same.
- **$\dot{V}O_{2max}$**: This is the maximum rate at which oxygen can be taken on and processed by the body. It's a good marker of aerobic fitness, and can also be used to express training intensity.
- **Training Zones**: In cycling training zones are often used to designate different training intensities. These can be based on power, heart rate or perceived effort level.

It should also be made clear that the recommendations within this guide are our own personal views. Importantly, this guide should not be construed as constituting medical advice. The optimal nutrition for you as an individual might be impacted by existing health conditions, pregnancy or medication, and we do not cover these instances within this guide. If you are in any doubt at all, please check with a medical practitioner before following any advice.

Chapter 1: Macronutrients

Overview of Macronutrients

Macronutrients are the essential nutrients required by the human body in large quantities to provide energy and support growth and development. There are three macronutrients: carbohydrates, proteins, and fats.

1. **Carbohydrates**: Carbohydrates are the primary source of energy for the body. They are found in foods such as grains, fruits, vegetables, and dairy products. Carbohydrates are broken down into glucose, which is largely either used by the body for energy, or stored in the muscles and liver as glycogen. Some is also converted to fat for storage.

2. **Proteins**: Proteins are essential for growth and repair of tissues in the body. They are found in foods such as meat, fish, eggs, beans, and nuts. Proteins are broken down into amino acids, which are mainly used by the body to build and repair tissues and to produce enzymes, hormones, and other essential molecules. Unlike carbohydrates and fats, the body uses only small amounts of protein to produce energy under most normal conditions.

3. **Fats**: Fats are important for energy storage, insulation, and the production of hormones. They are found in foods such as nuts, seeds, oils, butter, fatty fish and meats. Fats are broken down into fatty acids, which are used by the body for energy and to build cell membranes and other structures. Fat is stored in adipose tissue (also known as fat tissue), as well as in the muscles in the form of triglycerides, and in the blood in the form of free fatty acids.

Each macronutrient plays a variety of important roles in the body, and a balanced diet that includes all three is essential for optimal health.

It’s worth mentioning that alcohol is another source of energy, and is neither a carbohydrate, protein or fat (although many alcoholic drinks also contain carbohydrates). Perhaps it’s obvious, but alcohol is not an essential nutrient, but it’s important to be aware that it does contribute energy (i.e. calories) to your daily intake if consumed!

Carbohydrates and Fats

Carbohydrates provide a vital fuel source during all cycling activity, and across all intensities and is the primary fuel source used by the brain[1].

Carbohydrate is so critical to cycling, because of the efficiency and speed with which it can be converted into energy. The body can produce energy from carbohydrates in two ways. The first is known as 'anaerobic glycolysis', and is a process that happens very quickly, and is able to support energy production at a very high rate. This is because anaerobic glycolysis doesn't require oxygen to produce energy. The draw-back of anaerobic glycolysis though is that (i) it's less efficient, meaning you produce less energy per gram of carbohydrate and (ii) it results in a build-up of 'metabolites', which can quickly cause fatigue.

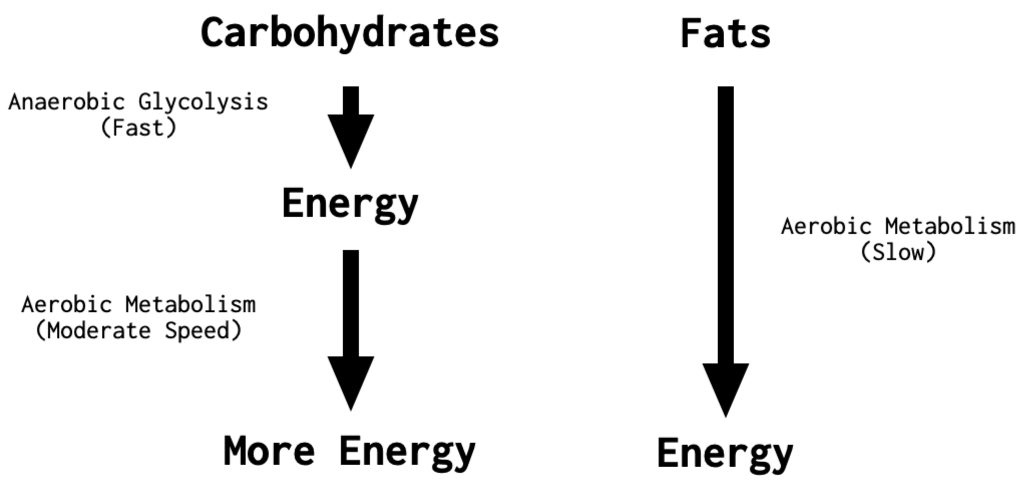

Figure 1. Pathways for producing energy from carbohydrates and fat.

The second pathway through which energy can be produced from carbohydrate is aerobic metabolism. This is a slower process, that requires the presence of oxygen to produce energy. However, this system is more efficient, and doesn't produce any fatiguing metabolites, meaning exercise can be sustained indefinitely via aerobic metabolism, until carbohydrates are used up.[2] These processes are illustrated in Figure 1.

Fats also provide an important source of energy during cycling. However, these are largely used at low and moderate intensities, because the process for producing energy

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[1] Except when the body is in a special metabolic state called 'ketosis', which we discuss later in this book.

[2] These two systems are actually inextricably linked, and carbohydrates broken down through anaerobic glycolysis will then typically be broken down via aerobic metabolism, unless there is insufficient oxygen present. Contrary to popular belief, both energy systems will always be operating concurrently, and there isn't an exercise intensity or power output where you step from being 'aerobic' to 'anaerobic'. Further details about energy systems can be found in our Cycling Physiology and Training Science Guide.

from fat takes longer than it does for carbohydrates. When riding at higher wattages, fat simply doesn't produce energy fast enough! The break-down of fat to produce energy is also an 'aerobic' process, meaning it requires oxygen.

The relative proportions of fat and carbohydrates that are used to produce energy via the aerobic system depends on exercise intensity, as illustrated in Figure 2. The use of fat dominates at lower intensities, where fat oxidation can keep pace with energy demands. The use of carbohydrates dominates at higher intensities, because this is a faster energy-production process.

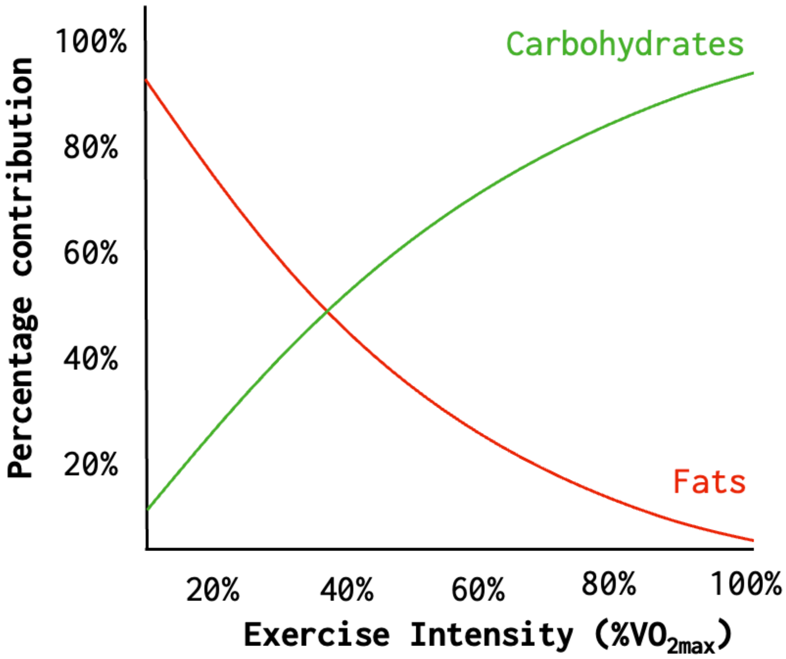

Figure 2. Relative contribution to energy production from fats and carbohydrates with increasing exercise intensity. Figure adapted from Brooks & Mercier (1994).

It's worth noting that at least some carbohydrate is used at all intensities; even very low intensities. This concept is often summed up by the expression that 'fats burn in a carbohydrate flame'. In other words, you can't burn fats without a little carbohydrate available.

The average endurance cyclist stores roughly 1500-2500 kcals of glycogen in their muscles, which is roughly enough to fuel around 1.5-2 hours of riding at race-pace. As the body's carbohydrate stores are depleted, the ability to produce high-power efforts becomes reduced. Moreover, when the carbohydrate stores fall below a critical threshold, then perceived effort level will ramp up exponentially, which is often referred to as 'bonking' or 'hitting the wall'. This is thought to be a protective mechanism to prevent the complete depletion of muscle glycogen stores, and is why taking on carbohydrates at appropriate points around training and competition is a cornerstone of sports nutrition, and something we'll discuss in detail through this guide.

In contrast to carbohydrates, even very lean cyclists have enough fat to fuel exercise lasting for several days. Therefore, intake of fats during and around exercise is less important. However, what's more important is the consideration of factors that can enhance or suppress the capacity to use fats for fuel when riding. This has a big impact on endurance, where a better ability to use fats for fuel leads to better endurance and ability to produce high-power efforts in the later stages of a ride. It also influences threshold power (e.g. FTP or more specifically lactate threshold power), where a higher capacity to use fats results in a lower rate of production of fatiguing metabolites.

Factors that impact the capacity to use fats for fuel include:
- Training status, where more well-trained cyclists will use more fat, and less carbohydrate for a given relative intensity.
- Prior nutrition, where eating carbohydrates tends to increase carbohydrate oxidation and suppress fat oxidation, for example.
- Caffeine use, where caffeine intake tends to increase fat oxidation capacity.
- Gender, where females tend to oxidise more fat and less carbohydrate at a given relative intensity.
- Time of day, where fat tends to be oxidised more easily later in the day.
- Environment, where extreme cold can increase reliance on carbohydrates, for example.
- Genetics, where some people have a natural tendency towards fat or carbohydrate metabolism.

Knowing these factors can help you to adjust your nutrition to enhance and/or compensate for shifts in fat oxidation capacity. We'll explain more about this later in the guide.

Glycemic Index

The glycemic index (GI) is a score between 0 to 100 given to foods containing carbohydrates. It indicates the degree to which a carbohydrate elevates blood glucose two hours after consumption. In effect it tells you how rapidly carbohydrates hit your blood stream after eating. The higher the GI of a carbohydrate, the more rapid is the increase in blood glucose. The highest score of 100 represents consuming pure glucose.

Understanding the GI of different foods is important in the context of cycling nutrition, because it impacts how quickly the carbohydrates become available for use during exercise, as well as how the carbohydrates are used, and at certain points we will recommend using high/low GI carbohydrates.

You can look up the glycemic index of various food using a database, such as the one provided by the University of Sydney (www.glycemicindex.com). However, broadly-speaking, foods that contain high amounts of sugar or refined carbohydrates tend to be higher on the GI scale. Examples of high-GI foods include, sugary drinks, sweets, chocolate bars, energy drinks/gels, white bread, white rice, white pasta, cakes, jam and honey, dried fruit and fruit juice.

The GI score is influenced by a number of complex and interrelated factors, but generally is reduced when foods contain soluble fibre, fat and protein, as well as certain compounds like ‘phytates’ and ‘polyphenols’. Examples of lower GI foods include wholemeal bread, pasta and rice, beans and lentils, oats, as well as many (but not all) fruits and vegetables.

Some starchy foods that have been cooked and then cooled (and potentially then reheated) also have a lowered glycemic index, because they develop so-called ‘resistant starches’, which behave like fibre. Examples include cold, cooked potatoes, pasta and rice.

Protein and Amino Acids

Unlike fats and carbohydrates, protein is not a preferred fuel in cycling. Instead, its main role is to provide the building blocks that enable training adaptations to take place.

In particular, it’s essential for the synthesis of new muscle, acting as both a trigger and a substrate for muscle protein synthesis. It also supports adaptations in non-muscle tissues, such as bones and ligaments. Importantly for endurance cyclists, it’s thought to be necessary in mitochondrial biogenesis (a key determinant of $\dot{V}O_{2max}$ and FTP, as well as other key cycling abilities). Protein can also help with recovery and the restoration of muscle glycogen levels, as we’ll cover later in this guide.

Amino Acids

The building blocks of proteins are called ‘amino acids’. Although there are hundreds of amino acids found in nature, only about 20 amino acids are needed to make all the proteins found in the human body.

Some of these amino acids can be produced by the body from other amino acids and substrates. However, nine amino acids can only be obtained through diet, and cannot be synthesised by the body. These are known as ‘essential amino acids’. The essential amino acids are:

- Phenylalanine
- Valine
- Tryptophan
- Threonine

- Isoleucine
- Methionine
- Histidine
- Leucine
- Lysine

The term ‘complete protein’ is used to refer to foods that contain all 9 essential amino acids. Key sources of complete protein include meat, fish, eggs, dairy and soy-based products like tofu, tempeh, edamame beans, and miso.

While it might seem that ‘complete proteins’ are better, or perhaps even essential to the diet, this isn’t actually the case, because it’s perfectly possible to get the full spectrum of essential amino acids by combining several incomplete proteins. Vegetarians and vegans therefore aren’t at a disadvantage in that regard. For example, wholemeal toast with nut butter or rice and beans are meal combinations that can provide the full spectrum of essential amino acids, even though the composite foods do not.

You’ll sometimes see reference to the term ‘high quality proteins’. This refers to complete proteins, but also to a combination of incomplete proteins that, when combined together, provide the full spectrum of essential amino acids.

Chapter Summary

- The three essential macronutrients are carbohydrate, fat and protein. All three are essential to health and to support training and performance.
- Carbohydrates and fats are primary sources of energy during exercise. Both substrates are used to some extent at all intensities. However, as exercise intensity increases, the proportion of energy derived from carbohydrates increases, as this is a faster source of energy.
- Carbohydrates are stored in the body in the form of blood glucose, and glycogen in the liver and muscles. Relative to fat, the body’s internal stores of carbohydrate are very limited, and depletion of these carbohydrate stores is one of the primary causes of fatigue in endurance cycling.
- Improving the capacity to use fats for fuel can help extend endurance by preserving glycogen stores. It can also help to improve threshold power.
- Glycemic index is a measure of how quickly a carbohydrate enters the bloodstream and increases blood glucose levels. A score of 100 represents pure glucose.
- Proteins are made up of amino acids. These are building blocks that enable training adaptations to take place.

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Chapter 2: Micronutrients

Overview of Micronutrients

Micronutrients are nutrients that are required by the body in small amounts but are essential for good health and proper bodily function. Unlike macronutrients, which are needed in large quantities, micronutrients are needed only in small amounts.

There are two main categories of micronutrients: vitamins and minerals.

1. **Vitamins**: Vitamins are organic compounds that the body needs to perform various functions, such as energy production, immune system function, and the maintenance of healthy skin and bones. There are two types of vitamins: fat-soluble vitamins (A, D, E, and K), which are stored in the body's fat cells, and water-soluble vitamins (B vitamins and vitamin C), which are not stored in the body and therefore need to be consumed daily.

2. **Minerals**: Minerals are inorganic compounds that the body needs for a wide range of functions, such as the formation of bones and teeth, muscle contraction, and the maintenance of proper fluid balance. Minerals are divided into two categories: major minerals, which are needed in larger amounts (such as calcium, magnesium, and potassium), and trace minerals, which are needed in smaller amounts (such as iron, zinc, and selenium).

It’s important to have a well-balanced diet that meets both your macronutrient and micronutrient needs, and a deficiency in any micronutrient could hamper training by impairing your health or the way your body functions more generally.

That said, there are several key micronutrients that have particularly important roles in exercise, and/or which are commonly low in the diets of many endurance cyclists.

Note that the recommendations given below are for the general population, and do not relate to pregnant or breastfeeding women, or people with specific medical conditions, who may require different intakes. Recommendations also vary across different authorities. The recommendations given below are those set by the UK Department of Health (Department of Health, 1991; SACN, 2016)

Iron

Role in Cycling

Iron is an essential mineral that plays a critical role in cycling training and performance, as well as health. Iron is necessary for the formation of haemoglobin, a protein found in red blood cells that carries oxygen from the lungs to the muscles, and removes waste carbon dioxide.

One of the key adaptations that we're looking to achieve from endurance training is an increase in the mass of haemoglobin in the blood. For this reason, cyclists have increased iron requirements above the general population. Iron is also important for the formation of myoglobin, which help carry oxygen within the muscles, and plays a direct role in energy production via the so called 'electron transport chain' (a very important energy-production process).

In real terms, if the body doesn't have enough iron, this typically means a reduced $\dot{V}O_{2max}$, functional threshold power (FTP), impaired capacity to ride above FTP before hitting fatigue, and slower recovery from hard efforts. Insufficient iron is also linked with general feelings of fatigue and increased risk of illness, which can significantly hamper training motivation and/or consistency.

It's worth noting that the terms 'iron deficiency' and 'anaemia' are often used interchangeably. However, they are not the same. Anaemia is defined as a lack of haemoglobin in the blood, whereas iron deficiency is a decrease in the total content of iron in the body. It is possible for an athlete to be iron deficient but not anaemic. Moreover, it's also possible for an athlete to not meet a clinical definition of iron deficiency, but for iron levels to still be low enough to negatively impact performance. It's therefore helpful to consult with a sports medicine practitioner if you intend to do any blood testing (see below), so that the results can be appropriately interpreted.

Key Food Sources

- red meat
- poultry
- fish
- legumes (e.g. beans and lentils)
- nuts
- tofu
- leafy greens such as spinach
- fortified cereals

Daily Recommendations

The basic recommendations for the general population are:

- Men and post-menopausal women: 8.7mg/day
- Pre-menopausal women (19 years and above): 14.8mg/day

However, the requirements of endurance athletes, including cyclists, have been estimated to be 70% higher than general recommendations.

In addition, vegetarian and vegan athletes may need yet higher intakes, because iron from plant-based foods is harder to absorb (this is known as having a 'low bioavailability'). The ‘bioavailability’ of iron can be increased by consuming iron-rich foods alongside vitamin C-rich foods such as citrus fruits, peppers, tomatoes and cruciferous vegetables (e.g. broccoli, Brussels sprouts, cabbage, cauliflower).

Cyclists who spend time at altitude (such as at training camps) may have acutely heightened requirements for iron while their body adapts to this environmental stress. This is due to the increased production of haemoglobin in the blood.

At Risk Populations

- Vegetarian and vegan athletes.
- Those with low energy intakes.
- Pre-menopausal women, particularly those with heavy periods, who are generally advised to take an iron supplement.

Vitamin B12

Role in Cycling

Like iron, vitamin B12 is also critical for the production of oxygen-carrying red blood cells. In addition, B12 is involved in the metabolism of carbohydrates, proteins, and fats, in the synthesis of DNA, which is necessary for the growth and repair of muscle tissue, and in the production of neurotransmitters that play a role in mood regulation and can help reduce feelings of fatigue and improve recovery after exercise.

Key Food Sources

- Beef liver and other organ meats.
- Clams, mussels, and other shellfish.
- Fish, such as salmon, trout, and tuna.
- Poultry, such as chicken and turkey.
- Eggs and dairy (in far lesser amounts to the above).
- Fortified breakfast cereals, plant milks and nutritional yeast.

Daily Recommendations

Guidelines for the general population are to consume:

- 1.5 micrograms/day for both men and women aged 19 to 64. Older athletes may require slightly higher doses (e.g. roughly 2.4mg/day)

There's an argument that cyclists may need slightly higher intakes of B12 due to the increased production of red blood cells and growth and repair of muscles.

At Risk Populations

- As B12 is not found naturally in any plant-based foods, and is in relatively low amounts in eggs and dairy, vegetarians and vegans are at high risk of B12 deficiency. Many authorities recommend that vegans take a B12 supplement.
- Older adults (> 50-years) are also at increased risk, as they can become less efficient at absorbing and utilizing vitamin B12.
- Individuals with gastrointestinal disorders, such as Crohn's disease or celiac disease are at heightened risk, as these conditions can interfere with the absorption of vitamin B12.

Calcium

Role in Cycling

Calcium is well known for its important role in maintaining bone health. However, it has countless other roles in the body too. Of particular relevance to cycling, it plays a crucial role in muscle contraction. Calcium is stored in the 'sarcoplasmic reticulum' of muscle cells and is released when a muscle is stimulated to contract. The release of calcium ions triggers a series of biochemical reactions that directly lead to muscle contraction. Calcium also helps to regulate heart rate during exercise, and control vascular function.

Key Food Sources

- Dairy products (e.g. milk, yogurt, cheese).
- Leafy green vegetables (e.g. spinach, kale, broccoli).
- Soy products (e.g. tofu, soy milk).
- Fortified cereals and breads.
- Nuts and seeds (e.g. almonds, sesame seeds).
- Fish with edible bones (e.g. canned salmon, sardines).
- Calcium-fortified plant-based milks (e.g. almond milk, oat milk).

Daily Recommendations

- 700mg for both men and women aged 19 to 64. Many sources recommend higher intakes (e.g. ~1200mg) for older adults over 64 years.

There is no change in these requirements for cyclists.

At Risk Populations

- Postmenopausal women, due to the hormonal changes that occur after menopause that can lead to bone loss.
- Older adults more generally, who may have decreased calcium absorption and increased calcium excretion.
- Those who do not consume dairy products and/or fish with edible bones (e.g. vegetarians, vegans, and lactose intolerant people).
- People with certain medical conditions affecting calcium absorption, such as celiac disease, inflammatory bowel disease, or chronic kidney disease.
- People who consume high amounts of caffeine, alcohol, or sodium, which can increase calcium excretion.

Vitamin D

Role in Cycling

Vitamin D is important for a wide variety of bodily functions. However, of particular relevance to cycling, it is essential for proper absorption of calcium and the key calcium-dependant functions described above.

Vitamin D also plays a role in the immune system and anti-inflammatory defences, thus helping to keep us healthy and maintain consistent training. There is some evidence to suggest it could directly support neuromuscular function and strength.

Key Food Sources

We obtain the vast majority of our vitamin D from the sun. However, there are some food-based sources too:

- Oily Fish.
- Cod Liver Oil.
- Some fortified foods such as margarine, milk etc.

Daily Recommendations

Recommended intakes for the general population are:

- 10 micrograms/day for both men and women over 19.

There is no change in these requirements for cyclists.

At Risk Populations

- Those with darker skin tones.

- Those who spend many hours indoors during sunlight hours.
- Those who regularly cover the majority of their skin (e.g. due to cold climate or religious reasons).
- Those living further from the equator.

It's estimated that 50% of the worldwide population have insufficient vitamin D levels, and many authorities recommend taking a daily vitamin D supplement of 10 micrograms per day, particularly if you are in an at-risk group.

Taking a vitamin D supplement while also spending a lot of time in the sun won't cause you to overdose on vitamin D, because your body will only make as much of the vitamin as it needs. However, you should take care not to double-up supplements (e.g. by taking a multi-vitamin containing vitamin-D, and a cod liver oil supplement, for example). This can lead to an excessive build-up of calcium and associated side effects.

Zinc

Role in Cycling

Like vitamin B12, zinc is involved in the synthesis of DNA and thus is essential for muscle growth and repair. It acts as a catalyst during energy metabolism, and helps to regulate the removal of waste carbon dioxide, which is generated during exercise. Zinc also has antioxidant properties that may help protect the body from oxidative stress, which can occur during exercise. Indeed, zinc has been shown to support immune function, which is important for cyclists who may be at a higher risk of infections due to heavy training loads.

Key Food Sources

- Meats e.g. beef, pork, lamb, and chicken.
- Seafoods e.g. oysters, crab, lobster, and shrimp.
- Dairy foods.
- Beans, legumes, nuts and seeds.
- Whole grains e.g. wheat, rice, and quinoa.
- Vegetables such as spinach, mushrooms and peas.

Daily Recommendations

Recommendations for the general population are:
- 9.5mg/day for men aged 19 to 64.
- 7.0mg/day for women aged 19 to 64.
- Several sources suggest higher intakes in older adults (e.g. 11mg for men and 8 mg for women over 70).

The bioavailability of zinc in different foods can vary. Animal sources of zinc, such as meat and seafood, are generally more bioavailable than plant sources of zinc. It's therefore been suggested that vegetarians and vegans may need around 50% more zinc per day.

At Risk Populations

- Vegetarians and vegans, and/or those following a high-carbohydrate diet, leading to relatively low intakes of animal-based fats and proteins.

Micronutrient Testing

Blood tests can be used to test your micronutrient status for all the key vitamins and minerals outlined above. We'd recommend arranging blood tests every 6-12 months if you suspect a deficiency or fall into one of the high-risk groups.

There are numerous 'finger prick' blood tests that can now be purchased online, where you collect a small blood sample at home and send this in the post to be assessed. However, the accuracy of these tests is often poor, and we'd recommend visiting a testing clinic to provide a larger venous blood sample, rather than using one of the home-based 'finger prick' tests.

We'd also recommend consulting with a medical practitioner before undertaking any testing to make sure the correct blood markers are being assessed. For example, in order to properly test for iron deficiency and/or anaemia, quite a wide range of markers ideally need to be collected, including a complete blood count, haemoglobin level, blood iron level, and ferritin level.

We also recommend consulting with a sports medicine practitioner when you receive your results, as they will be better able to interpret your blood test values in the context of your cycling needs.

Supplementation

You may be wondering whether you should be taking supplements to help ensure adequate micronutrient intakes. The golden rule with supplementation is 'first do no harm'. In other words, before supplementing, you should always consider whether this could have any deleterious effects.

Taking certain supplements can interfere with the absorption of other micronutrients, and with certain medications, and in very high doses can sometimes be toxic. There's also a risk that supplements can contain harmful or banned substances, which can be introduced through cross-contamination at the point of production. In addition, supplementation can be associated with side effects, such as nausea, stomach discomfort, headaches, and constipation/diarrhoea. Since the use of vitamin and mineral supplements does not improve performance in individuals consuming nutritionally adequate diets, in most cases, where the baseline diet is adequate and where no pre-existing deficiency exists, supplementation is not advisable.

That said, there are some instances where supplementation is recommended:

1. Iron supplementation is often recommended in menstruating females, and particularly those who have a low energy intake, follow a vegetarian or vegan diet, and/or have heavy bleeding. We recommend using ‘Floradix’ liquid or tablet supplement, or ‘Spatone’ water-based shots, as these have good bioavailability, and people generally experience fewer side effects such as stomach discomfort/nausea, constipation, and diarrhoea.
2. Vitamin D supplementation at a dosage of 10 micrograms or 400IU per day is usually recommended for adults living far from the equator, or those who work indoors or remain covered up for large parts of the day. Do not take more than 100 micrograms (4,000 IU) of vitamin D a day as it could be harmful.
3. A vitamin B12 supplement is recommended for vegans. The daily requirement for vitamin B12 is 1.5 micrograms/day (with cyclists needing slightly more than this). However, you’ll generally find vitamin B12 in much higher doses than this. This is because B12 is a water-soluble vitamin, meaning any excess is excreted in urine, so there is no risk of overdosing.

In any event, you should always consult with a medical practitioner before taking any supplements, to ensure they are safe to take, and will not interfere with any medications you’re taking.

Chapter Summary

- There are two main categories of micronutrients: vitamins and minerals. These are important for maintaining health, and many also play vital roles in supporting training, facilitating adaptations, and optimising performance.
- Some key micronutrients to be aware of include iron, vitamin B12, calcium, vitamin D and zinc.
- Generally-speaking, adequate micronutrients can be obtained through a balanced diet. However vegetarians and vegans may need to take particular care and consider supplements in some instances.
- Those living far from the equator, or who don’t get significant exposure to sunlight may also be at risk of vitamin D deficiency, and menstruating females with heavy periods may be at increased risk of iron deficiency.

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Chapter 3: Fundamentals for Health

Balanced Diet

The first, and most important thing to consider, before we cover any sport-specific nutrition recommendations, is the fundamentals of a balanced diet. Consuming a diet that provides all the necessary macronutrients, micronutrients, and essential amino acids is the foundation to any cycling nutrition plan.

We can think of this like base training in cycling. Unless you have a well-developed aerobic base, then working on your top-end abilities like anaerobic power won’t get you to a very high level overall. In much the similar way, unless you have a good nutritional foundation that provides your body with all the building blocks you need to function and stay healthy, then optimising and fine-tuning specific sports nutrition practices, such as supplements, won’t get very far with either!

Indeed, it’s helpful to think of sports nutrition as a pyramid with a balanced diet on the lowest level, as shown below. If this foundational level is missing, the ‘height of your pyramid’ (i.e. potential performance gains) is reduced.

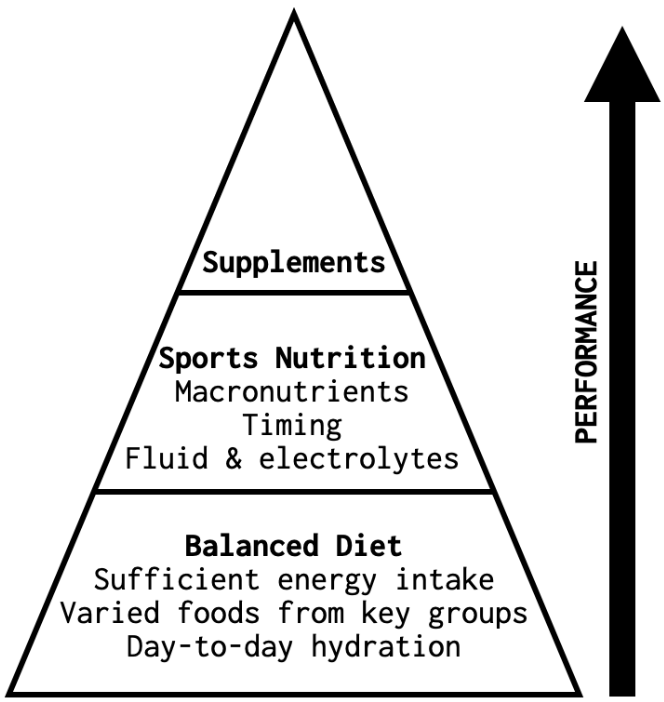

Figure 3. Sports nutrition pyramid, illustrating the importance of a balanced diet as a foundation to optimal performance.

Sitting atop the balanced diet are various sports nutrition best practices, which involve manipulating the timing, type and amount of food and fluid intake to optimise performance and/or training adaptations, or allow for consistent and high-quality training sessions.

Finally, sports supplements sit at the final level, allowing you to eke out any final performance/adaptive gains. This level only works as intended if you have the first two levels optimised. For example, there’s no point taking a supplement that boosts your endurance, if you haven’t taken on the correct fuel to sustain the effort!

A balanced diet can take many forms, and it’s perfectly possible to achieve a balanced diet from a pescatarian, vegetarian or vegan diet, for example.

The fundamental components that you’ll want to hit are:

- At least 5-portions of fruits and vegetables per day. A portion is roughly 80g, and you should try to consume a wide variety of these foods within the day, and across the week.
- Eat wholegrain carbohydrates, such as wholegrain cereals, oats, brown bread, pasta and rice.
- Consume between 3-5 servings of protein-rich food (15-25g protein per serving) per day, which can include protein from meat, seafood, dairy and plants (e.g. beans, legumes, nuts, seeds and soya-based products). Try to have a variety to make sure you get a spectrum of essential amino acids.
- Consume between 2-4 servings of calcium-rich foods per day, which can include dairy products as well as calcium-fortified plant-based alternatives.
- Drink at least 6-8 glasses of fluids (~1.2L in total), plus additional fluids during exercise. Fluids include water, tea, coffee, milk, fruit juice etc.

Vegetarians and vegans may need to pay particular attention to consuming sufficient omega-3, which can be obtained from walnuts, linseed, or supplements.

Vegans may additionally need to pay attention to intakes of B12, iodine and selenium, which can be harder to obtain from plant-based sources. B12 is often included in fortified foods such as plant-based milks or nutritional yeast, or can be supplemented as discussed in Chapter 2. Iodine can be found in some fortified plant-based milks, or by eating nori strips (1.5-2 sheets per day). Selenium is present in high amounts in Brazil nuts. But be careful not to over-eat these, as too much selenium can be toxic - generally no more than 1-3 Brazil nuts per day is recommended. Alternatively, a high-quality vegan multivitamin can be taken. We’d recommend consulting a medical practitioner for a recommendation.

Energy Demands

Another fundamental for maintaining health and supporting training and performance is to ensure adequate energy intake. Insufficient energy intake (where energy intake is significantly below energy expenditure) can have numerous negative health and performance implications, as we discuss in more detail in the weight loss chapter later in this guide.

The energy content of foods is usually expressed in kilocalories or kcal (colloquially termed ‘calories’), where 1 kcal is 4.18kJ of energy.

Your daily energy demands are made up of three key components:
1. Your resting metabolic rate. This is the energy used when at complete rest and while fasted. It’s largely attributable to bodily processes involved in maintaining body temperature and normal bodily functions and is the biggest contributor to your daily energy expenditure.
2. The ‘thermic effect of feeding’. This is the energy used by the body in digesting food.
3. The ‘thermic effect of activity’. This is the energy used when moving around or engaging your muscles. This includes the countless small movements/activities you make throughout the day, such as sitting at a desk and typing, driving, picking something up, as well as more obvious activities like riding, walking, and running.

Factors that tend to increase energy demands include exposure to cold, heat, altitude, stress, injury, or illness. Other factors include drug use (including caffeine and nicotine), muscle mass, and phases of the menstrual cycle, although menstrual phase hasn’t been conclusively shown to impact energy needs.

Estimating Energy Demands

<u>Step 1: Estimate RMR</u>

To estimate your energy requirements, we recommend first using the ‘Cunningham Equation’ to estimate your resting metabolic rate (RMR):

RMR = 22 x FFM + 500

In this equation ‘FFM’ stands for ‘fat free mass’. You can work this out if you have a set of scales that measure your body fat percentage (see Chapter 6 for more discussion of these).

If you weigh 70kg, with a body fat percentage of 10%, then 7kg of your weight is attributable to fat, and the remaining 63kg is fat free mass.

Plugging the 63kg of fat free mass into the Cunningham formula above gives a resting metabolic rate of 1886 kcal. Note that your fat free mass needs to be entered into the equation in kg and not lbs.

If you don’t know your body fat percentage, you can use the Harris-Benedict equations below, although these can be less accurate, particularly for lean and/or muscular cyclists. The following equations estimate ‘basal metabolic rate’ (BMR) which has a slightly different definition to resting metabolic rate, and the value will come out lower.

MEN: BMR = 66.473 + (13.7516 × weight in kg) + (5.0033 × height in cm) - (6.755 × age in years)

WOMEN: BMR = 655.0955 + (9.5634 × weight in kg) + (1.8496 × height in cm) - (4.6756 × age in years)

Step 2: Estimate your non-training daily energy expenditure

The next step is to estimate your non-training daily energy expenditure. This is the amount of energy you'd typically burn in a day, if you weren't training on the bike or performing other intentional training (e.g. running/strength training).

To do this, we apply a multiplication factor (also known as a 'physical activity level' or PAL value) to your RMR/BMR value calculated at step 1. The table below shows PAL values for differing activity levels. Note the multipliers are slightly different depending on which equation you used (Cunningham vs Harris-Benedict). This accounts for the fact that BMR is slightly lower than RMR.

Activity Level	PAL Value Cunningham	PAL Value Harris-Benedict
Desk based work, with very little movement	1.15-1.25	1.4-1.5
Desk-based work, with low-levels of movement (e.g. walking to/from office and/or walking at lunch break)	1.3-1.4	1.6-1.7
Standing work (e.g. housework, shop assistant, waitress) or manual labour (e.g. bricklayer)	1.5-1.6	1.8-1.9
Additional activity performed daily or most days (e.g. walking the 60-mins over day, running 30-mins per day)	Add 0.2-0.3 onto your score from above	Add 0.3-0.4 onto your score from above.

Table 1. Physical Activity Level (PAL) values allowing estimation of non-training daily energy expenditure. Use 'Cunningham' values if the Cunningham equations was used to estimate resting metabolic rate. Use the Harris-Benedict values if the Harris-Benedict equation was used to estimate basal metabolic rate.

To give an example, if an athlete has an RMR of 1900 kcal (estimated with the Cunningham equation), they work from home in a desk-based job, and have very little physical activity aside from training on the bike, we would use a PAL value of around 1.2, giving this athlete a non-training energy requirement of 2280 kcal.

If the same athlete instead commuted into work via train, which involves some walking to/from the station, and often takes a short walk at lunch to get food, then we'd use a PAL value of 1.4, giving them a non-training energy requirement of 2660 kcal.

If the athlete also tended to walk their dog at a brisk walking pace for 30-mins 2x per day, then we'd add an extra 0.2 points to the athlete's PAL value. So, the score of 1.4 would increase to 1.6, and the athlete's non-training energy demands would be roughly 3050 kcal.

Step 3: Determine training energy expenditure

The final step is to determine how much energy you expend on the bike and in other forms of training. You can then add this to your non-training expenditure calculated in Step 2, to get your total daily expenditure.

If you have a power meter, then the task of estimating energy expenditure is very easy and actually quite accurate. This is because the amount of work done on a ride (measured in kJ) corresponds almost exactly to the amount of kcal expended[3].

So, if you do 1400 kJ of work on a ride, then you've burnt approximately 1400 kcal.

We recommend estimating your average daily energy requirement, by adding up the work done in all your rides across the course of a normal training week and dividing by 7. This will give you your average daily energy expenditure on the bike. This value can then be added to the non-training expenditure calculated in Step 2 to give you your total average daily expenditure.

For example, an athlete with a non-training expenditure of 2600 kcal, and who expends an average of 900 kcal per day on the bike, will have a total daily energy requirement of 3500 kcal on average.

We'd also recommend determining a range for your daily energy expenditure, so you have an idea of how much this might fluctuate. For example, if our athlete has one or two rest days with no training, and also typically does a 4H ride at the weekend, in which he burns 2400 kcal, then his range of daily energy expenditure is between 2600 kcal and 5000 kcal, which is quite a range!

If you don't have a power meter, and/or if you also need to estimate energy expenditure for other activities such as running or weight training, then it's a little harder to determine calories burnt. You'll need to calculate this using so-called 'MET' values, which express the rate of energy expenditure relative to RMR. To do this, you can use the following equation:

Energy expended = RMR (or BMR) x MET x (duration in hours / 24)

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[3] This is because 1 kcal = 4.18 kJ. At the same time, the human body is roughly 25% efficient in converting kcal burnt into watts on the bike. So for every 4kJ of energy burnt (roughly 1kcal), there is 1kJ of work done in turning the cranks on the bike.

MET values for common activities are shown below. You can also look online and view large compendiums of MET values for a wide range of activities if the ones below don't suit.

Activity	MET value
Recovery ride	7
Endurance ride	8
Interval session/hard group ride	9-12
Running @ 10 min/mile	9.8
Running @ 8.5 min/mile	11
Running @ 7min/mile	12.3
Strength training	3.5-6

Table 2. MET values for different types of common activities. More MET values can be found in online compendiums.

As an example, if you were to ride for 3H at an endurance pace, and had an RMR of 1900kcal, then your estimated energy expenditure would be:

Energy expenditure = 1600 x 8 x (3/24) = 1600 kcal

This value can then be added to your non-training energy demands, as before.

Chapter Summary

- Total daily energy expenditure can be calculated by first estimating your 'basal metabolic rate' (BMR) or 'resting metabolic rate' (RMR). These two terms are subtly different, but effectively tell you how many calories you burn when at complete rest and while not digesting any foods (which requires energy!).
- You can then estimate your total daily non-training energy expenditure using a 'PAL' or physical activity level value. This is a number that you multiply your BMR/RMR by, depending on how physical your day-to-day life is.
- Finally, you can estimate your energy expenditure in training. There are various ways you can go about this, depending on the type of activity and the data you have available. If you train with power, then the best method is to convert the work done in kJ to calories burnt in kcal. There is roughly a 1:1 relationship between these values, so 1 kJ of work done is equal to 1 kcal of energy burnt.

Chapter References

Vitale & Getzin, 2019

Desbrow et al., 2021

Thomas et al., 2016

Buttriss, 2016

Cunningham 1980

Harris & Benedict 1919

Black et al., 1996

Chapter 4: Training Nutrition - Daily Requirements

Summary of Macronutrient Requirements

The table below shows recommended daily intakes of fat, carbohydrate and protein to support training among those who are looking to maintain weight/body composition. If you're looking to lose weight or reduce body fat, then please refer to Chapter 6.

	Heavy Training (e.g. intervals, group ride, or long endurance ride)	Moderate Training (e.g. 1-2H endurance ride)	Recovery Day
Carbohydrate	6-12g /kg BW /day[1]	5-7g /kg BW /day	3-5g /kg BW /day
Protein	1.2-2.0g/kg per day[2]		
Fat	20-30% daily energy intake		

Table 3. Recommended intakes of carbohydrate, fat and protein, depending on type of training day. [1] Higher end of the range for intense and/or very long sessions (4-5H+), with intake determined to fit around total daily energy demands. [2] Higher end of the range for masters cyclists, weight-loss, if weight training 2-3x per week, or when there's an acute increase in training load.

This table can be used as a quick reference guide for your training. However, we recommend reading the further explanation and discussion in this chapter, as this will help you decide where you sit within these ranges.

Carbohydrate Periodisation

Carbohydrates form a central component of the diet for cyclists, and recommended intakes are higher than they are for the general population. This is for several reasons:

1. There are only limited stores of carbohydrates within the body, which need to be replenished during/after training sessions.
2. Carbohydrates provide a key fuel for brain, central nervous system and muscles.
3. Carbohydrates are used in both aerobic and anaerobic energy production processes, and support exercise across a range of intensities.
4. It's been shown in hundreds of studies that carbohydrates are performance-enhancing across a range of intensities, durations and exercise types (e.g. intermittent vs continuous).

Historically, carbohydrates have been prioritised as fuel source among endurance cyclists, irrespective of the type of training being done (e.g. whether you're doing a recovery ride, endurance ride or interval session).

However, it's now been appreciated that the availability (or more specifically, lack of availability!) of carbohydrates is a key stimulus for aerobic adaptation, and more recently the concept of 'dietary periodisation' has become popular.

With this approach, the intake of calories, macronutrients, and particularly carbohydrates are modulated from day to day depending on the type of session being performed, so as to enhance adaptations. This is a strategy we'll discuss in more detail in the next chapter. For now, it's enough to acknowledge that daily carbohydrate recommendations vary depending on the type of session you're doing, as well as your total daily energy expenditure.

Protein

The protein demands of endurance cyclists are also higher than for the general population[4]. This is to support metabolic adaptations, such as mitochondrial protein synthesis as well as repair and remodelling of muscle, ligaments, and other tissues. Relatively small amounts of protein are also used as fuel during exercise itself.

Protein requirements can be particularly high when a new type of training is introduced, and/or if training load is markedly increased (such as on a training camp). Protein intake should also be increased if looking to achieve a reduction in body fat through caloric restriction, as this helps to preserve muscle mass. We discuss this more in Chapter 6.

It's worth noting that there's an upper limit to how much protein can be used by the body to synthesise or repair tissues. At least for younger athletes (<40-50 years old), exceeding ~2g/kg body weight of protein per day doesn't appear to confer any additional training benefit, and any excess protein will generally be used for energy or converted into fat for storage.

A potential exception to this is among older individuals (e.g. 40-50-years and above), who may need higher intakes of protein to help maintain muscle mass, due to a condition known as 'sarcopenia', which accelerates loss of muscle mass. It's been shown that, among the general population, older individuals benefit from increased protein intakes, which provides a bigger signal to trigger muscle protein synthesis. It has, however, been questioned whether masters athletes require increased protein intake beyond the already elevated requirements of younger athletes. Some research suggests that simply

[4] Although they are not as high as for strength/power-focussed athletes, where particularly high intakes of protein are required to build muscle mass.

engaging in regular exercise is sufficient to help maintain muscle mass, and an elevated protein intake beyond more normal sports nutrition recommendations doesn't provide any additional benefit (Moore, 2021). In the absence of any conclusive evidence, we'd recommend aiming for the higher end of the normal guidance for endurance cyclists, if you're 40 or older (i.e. between 1.6-2.0g/kg body weight).
Another point worth noting here is that there's also a limit to the amount of protein the body can process to synthesise and repair tissues within an individual meal. This threshold seems to be roughly 15-25g per meal (or between 0.2-0.3g/kg body weight of high-quality protein). It's therefore recommended that protein intake is spread across the day in 3-5 smaller meals if looking to optimise the use of protein for tissue synthesis and repair.

Fat

The recommended intake for fat is in line with the recommendations for the general population, reflecting the important role fat plays in many aspects of health, including the synthesis of hormones, and provision of nutrients, including various vitamins and minerals as well as omega 3 and 6.

For health reasons, it's usually recommended that fat intake is mostly made up of unsaturated fats (found in e.g. nuts, seeds, oily fish and most plant oils), and that intakes of saturated fats (found in meat, dairy, cakes and baked goods, and in coconut oil) is limited to no more than 20g per day for women and 30g per day for men.

Balancing Macronutrients with Energy Demands

The ranges for daily carbohydrate, protein and fat intakes shown above are quite broad. This is, in part, to account for variations in total energy requirements.

In order to calculate more precise targets for macronutrient intakes, we recommend taking the following steps:

<u>Step 1: Subtract fat allocation</u>
As the recommended fat intake is the same for all types of training day, we recommend dealing with this first.

To get a ballpark estimate for your daily fat intake, find 25% of your daily energy requirement, by multiplying this by 0.25.

For example, if your daily energy requirement is 3000 kcal, then you'll need 0.25 x 3000 = 750 kcal from fat.

There are 9 kcal per g of fat. This means you should be aiming for roughly 750/9 = 83g of fat per day.

Step 2: Calculate g/day of carbohydrates and protein combined.

Quite conveniently, the calorie content of carbohydrates and protein is the same at 4 kcal per gram.

Now that we've subtracted our fat allocation, we can therefore calculate how many grams of carbohydrates and protein we have 'space' for within our energy budget.

In our current example, 750 kcal is allocated for fat and we therefore have 2250kcal remaining to be shared between protein and carbohydrates.

If we divide 2250 kcal by 4, we can convert this into grams.

So, we have 562.5g of protein/carbohydrates available in our energy budget.

Step 3: Convert into grams per kg body weight

Sports nutrition guidelines are generally expressed in terms of grams per kg of body weight. So, it makes things easier if we convert our remaining carbohydrate/protein budget into the same units.

In this step we therefore divide the remaining carbohydrate/protein budget (562.5g) by body weight (let's say 70kg), to get a budget of 8.0g/kg.

Step 4: Decide the best way to portion remaining energy budget

We know we must allow at least 1.2g/kg of protein per day, which leaves a maximum intake of 6.8g/kg of carbohydrates. If it was a heavier training day - particularly one with a lot of intensity - then we would probably settle upon this lower end of protein intake to maximise carbohydrate intake.

However, if it happens to be more of a moderate training day (e.g. perhaps just a 1.5-hour endurance ride) then we might opt to increase the protein intake towards 2g/kg body weight (which might be particularly helpful if you are looking for weight loss, are a masters athlete, or are doing some concurrent strength training). This would bring the carbohydrate allocation down to 6g/kg or thereabouts.

It's absolutely fine to play around with your values a bit at this stage. For example, if you find that there isn't much budget left for carbohydrates, yet you have a particularly hard/intense session planned, then we could go back to step 1 above, and allocate just 20% of energy intake to fat, which allows more 'budget' for carbohydrates.

Bear in mind also that alcohol contributes energy that's not accounted for in your budget above. Alcohol contains 7 kcal per gram, and if you intend to drink, then you need to subtract this from your energy budget at the outset (i.e. before Step 1).

Nutrition Tracking & Meal Planning

Having calculated your energy and macronutrient requirements, you might be wondering how exactly to use this information.

There are two key ways this information can be used, depending on your preferences.

First is to use this information in conjunction with a diet tracking app, such as MyFitnessPal. This is a database of the energy and macronutrient break-down of thousands of foods and drinks. You can use this app to record everything you consume on a given day, and to see how well this agrees with your estimated energy and macronutrient targets.

Now, we don't generally advocate for diet tracking over a long period of time, firstly because it's time-consuming, and secondly because it can trigger disordered eating habits.

However, we do believe it's useful to record your intake over 3-4 'normal' training and eating days (i.e. days that you feel are quite reflective of your usual training load and eating patterns). You can then use this to help 'calibrate' your intake going forward. For example, if you spot that your fat intake is generally a little higher than your target intake, and carbohydrate is a little lower, then you can plan to make some small changes to the way you eat going forward to help emphasise carbohydrate intake and de-emphasise fats. You can then do another 3-4 day assessment a few months down the line to see whether things have improved.

Taking this approach should, over time, help you get an intuitive sense of how much you need to eat, and in what proportions to broadly hit your energy and macronutrient targets. Of course, there will be days where you don't hit your targets for whatever reason, but over time you will learn to identify these occasions, and can adjust your training or subsequent nutrition to account for this.

Another option is to use a meal planner. You can either pay a nutritionist to put together a meal plan for you, which aligns with your target intakes (bearing in mind, you'll probably need different plans to suit the different types of training day that you have). Alternatively, there are some automated meal planners available online. A free option is www.eatthismuch.com, which can accommodate various dietary requirements/preferences.

Low-Carbohydrates/Ketogenic Diets

In recent years, there has been considerable attention given to low carbohydrate and/or ketogenic or 'keto' diets in the popular media. A key example is the 'Atkins Diet', although there are many other versions too.

A low-carbohydrate diet is generally defined as one where carbohydrate intake is limited to less than 25% of total energy each day (roughly 125g/day for someone consuming 2000 kcal per day).

A ketogenic diet restricts carbohydrate intake further (down to roughly 50g per day), and is intended to trigger the body to enter a metabolic state of 'ketosis', where fats are converted into 'ketones', which are used for energy[5]. Carbohydrate intake must be kept very low at all times to stay in this state of ketosis. Simply following a low-carbohydrate diet as described above doesn't trigger this metabolic state.

Both a low-carbohydrate and a ketogenic diet have been shown to improve capacity for fat oxidation, and this can be achieved in as little as 5-6 days on a ketogenic diet. This can help improve endurance and (in theory) potentially lift threshold power/FTP, as we discuss in more detail in Chapter 5. Much research has therefore been performed to examine whether following a low-carbohydrate or ketogenic diet may be performance-enhancing.

However, it's now widely accepted that following a low-carbohydrate/ketogenic diet is detrimental to performance and training adaptations in almost all cycling disciplines. This is because it impairs the ability to produce energy quickly, via glycolysis (i.e. the break-down of carbohydrates), which in turn may have a detrimental impact on the ability to complete key high-intensity training sessions or to compete at higher intensities.

Moreover, this suppression of glycolysis persists even if the body's carbohydrate stores are subsequently replenished by 24-48 hours of 'carbohydrate loading' (i.e. consuming high-carbohydrate intakes over 1-2 days)[6]. In effect, a carbohydrate-restricted diet seems to reduce so-called 'metabolic flexibility', or in other words, the ability to switch between the slower but more abundant fuel source of fat, and the faster fuel source of carbohydrate, in response to changes in exercise intensity.

Almost all cycling disciplines benefit from the ability to switch between fuel sources and produce energy rapidly from carbohydrates when intensities are higher. The only potential exception to this is for very long, steady time-trials (e.g. 12- or 24-hour time trials) or ultra-distance events on a flat route, where intensity is entirely below FTP/threshold power. In this case, there may be a potential benefit (or at least no performance detriment) to following a low-carbohydrate or ketogenic diet for 5-6 days leading into a key event, followed by 24-hours of carbohydrate-loading. However, the evidence supporting this nutritional strategy is weak at best, and not one we'd be inclined to recommend, even under these limited circumstances.

[5] As mentioned above, under usual circumstances, the primary fuel used by the brain is carbohydrate. However, when the body is in a state of ketosis, triggered by exceptionally low carbohydrate intake, ketones provide fuel for the brain.

[6] For more discussion on carbohydrate loading protocols, please refer to Chapter 8.

Chapter Summary

- Daily macronutrient intakes need to meet both your total daily energy demands, as well as the needs of a particular training day.
- Different types of training day have different dietary needs. This is particularly true for carbohydrates, where high-intensity training/competition days benefit from high carbohydrate intakes, whereas lower-intensity training days and shorter recovery days may be better suited to lower carbohydrate intakes.
- It can be useful to track your dietary intake over a short period of time to see how your intake compares to your requirements. This can help you identify any changes you may need to make. We don't advocate continual dietary tracking though.
- Low carbohydrate and/or ketogenic diets are likely to be detrimental to most cycling disciplines, with the possible exception of long, flat time trials or ultra-distance events lasting many hours, where there is no need to ride close to or above threshold at any point.

Chapter References

Vitale & Getzin, 2019
Desbrow et al., 2021
Thomas et al., 2016
Buttriss, 2016
Phillips & Van Loon 2013
Stellingwerff et al., 2019.
Moore 2021
Burke et al., 2021
Burke et al., 2015

Chapter 5: Training Nutrition - Timing Considerations

Acute Nutrition Strategies

Table 4 summarises nutritional best practices before, during and after a training session. These recommendations are designed to help optimise training adaptations, and are explained more fully in this chapter.

Interval Sessions

For any high-intensity training sessions (i.e. those that involve riding at or above your threshold power/FTP), a significant portion of energy will be derived through carbohydrate metabolism. In order that you can achieve the high power targets needed for these sessions, we recommend fuelling with a carbohydrate-based meal/snack beforehand. Ideally, this would comprise **1-4g of carbohydrates per kg of body weight, and should be eaten 2-4 hours before the session** to avoid any gastrointestinal issues and to allow time for your blood glucose levels to stabilise before beginning exercise.

Many people train in the morning before work, and it's not always possible to eat 2-4H before a session. In these circumstances, we recommend consuming a **small carbohydrate-based snack or drink >10-mins before the session**, or even during the warm-up. While it takes some time for these carbohydrates to reach your blood stream, they can provide an immediate boost to your subjective energy levels when receptors in the mouth detect the carbohydrates and send a signal to the central nervous system. Examples of snacks that work well immediately before a training session (i.e. which are low-volume and easily digestible so as not to cause gastrointestinal problems), include a sports drink, bar or gel, a banana, a slice of jam on toast, a smoothie, milkshake or fruit juice, or some dried fruit or fruit loaf.

We recommend **avoiding eating between 10-60 minutes before a training session**, because after eating you will generally have a rapid rise and then fall in your blood glucose level before this stabilises. Beginning exercise during this period of lowered blood glucose can make exercise feel subjectively harder, and for interval sessions this is something you generally want to avoid as much as possible, because these sessions are tough at the best of times! We discuss this phenomenon more in Chapter 8.

You might benefit from having some **caffeine around 20-60 minutes before** an interval session. This can help make a session feel subjectively easier. We cover caffeine in Chapter 9, including appropriate dosages and sources.

	Before	During	After
Intervals	1-2g/kg BW carbs 2-4H before. OR Small carb-based snack <10-mins before ride or during warm-up if early morning session. Consider caffeine 20-60 mins prior.	Drink to thirst. Consider fuelling during ride if >2H. Aim for 45-60g/hour, or slightly more if riding longer than 3H.	Aim to eat a snack containing ~1g/kg BW carbs, with a little protein (e.g. 5-20g), around 30-mins after session complete. OR Avoid carbohydrate intake if planning carbohydrate restricted training the next day (eat protein and fat instead).
Endurance Rides <2H	No special requirements, but may wish to avoid eating during 1H before to avoid gastrointestinal problems.	Drink to thirst. No need for fuelling during. These sessions are good for carbohydrate restricted training.	If ride was done with restricted carbohydrate availability, follow guidance for endurance rides 2-5H. Otherwise, eat as desired.
Endurance Rides 2-5H.	No special requirements, but if doing a ride that challenges your endurance abilities follow guidance for endurance rides >5H.	Drink to thirst. Carbohydrates as required - typically 30g/H is sufficient.	Aim to eat a snack containing ~1g/kg BW carbs, with a little protein (e.g. 5-20g), around 30-mins after session complete.
Endurance Rides >5H	1-2g/kg BW carbs 2-4H before. OR Small carb-based snack <10-mins before or during warm-up if early morning session.	Drink to thirst. Carbohydrates as required - typically 45-60g/H is advisable.	Aim to eat a snack containing ~1g/kg BW carbs, with a little protein (e.g. 5-20g), around 30-mins after session complete.
Group Rides	1-2g/kg BW carbs 2-4H before. OR Small carb-based snack <10-mins before or during warm-up if early morning session.	Drink to thirst. Carbohydrates as required - typically 30-60g/H depending on intensity.	Aim to eat a snack containing ~1g/kg BW carbs, with a little protein (e.g. 5-20g), around 30-mins after session complete.
Recovery Rides	No special requirements	Drink to thirst.	No special requirements.
Resistance Training	No special requirements	No special requirements	Aim to eat 0.2-0.3g/kg BW high quality protein within 0-2 hours of training, and repeat every 3-4 hours. If doing high-intensity training on the bike the same day, also aim to eat a snack containing ~1g/kg BW carbs within 30-minutes, and repeat every few hours.

Table 4. Acute nutritional strategies for different types of training session. BW = Body Weight, carbs = carbohydrates, H = hours.

Drink to thirst during interval sessions, bearing in mind that your sweat rate can be high if you're training indoors.

After completing an interval session, we generally recommend having a snack within ~30-mins of the session. This should ideally comprise carbohydrates to replenish your muscle glycogen stores, and ideally some protein to help with repair and generation of new proteins in the body. This 30-minute window is when your muscles are most receptive to carbohydrates and the muscles' glycogen stores will be replenished most effectively. However, eating outside this window will still help replenish glycogen stores, so don't worry if you miss this window!

An exception to the refuelling guidance above is if you're planning to do a carbohydrate-restricted ride the next day (see further below). In this case you can restrict carbohydrate intake after an interval session, sticking mainly to protein and fats instead. We wouldn't recommend doing carbohydrate restricted sessions like this more than 1-2 times per week, due to the risk of inadequate total energy intake when following this strategy and the additional stress placed on the body. We'd also strongly recommend avoiding this nutritional strategy entirely if you already have a very low body fat, are susceptible to illness, or have low bone mineral density and/or symptoms of RED-S (see Chapter 6). We discuss carbohydrate-restricted training and how to use this strategy safely in more detail later in this chapter.

Endurance Rides

We define endurance rides as any ride that lasts more than 1-hour and is typically done predominantly at a Zone 2 intensity (~55-75% FTP, 2-4/10 effort level, or between 60-70% Max HR). These rides can possibly include smaller amounts of Zone 3 intensity (75-95% FTP, 5-6/10 effort or between 70-80% Max HR). These rides are predominantly fuelled by a combination of fat oxidation and carbohydrate oxidation. The extent to which you favour fat vs carbohydrate oxidation depends on your genetics and training status (plus some other factors such as prior fuelling, environmental conditions, and time of day).

Shorter endurance rides generally don't require any specific fuelling considerations, as the intensity will be low enough and duration short enough that your body's existing fuel stores will be minimally impacted. That said, we'd recommend avoiding eating too much in the ~1-2 hours before a session to avoid gastrointestinal problems. Beyond that, you can eat as convenient.

Shorter endurance rides (up to ~2H) can be good sessions to employ carbohydrate restricted training, if this fits with your training goals and doesn't present a risk to your health. As mentioned above, this is a topic we'll discuss in more detail later in this chapter.

Longer endurance rides may require some fuelling during the ride. The amount of fuelling required depends on your ability to use fats for fuel. You'll get a sense of how much you need to eat during these rides with practice. Given the low intensity of these training sessions, approximately 30g/hour of carbohydrates is a good target for many people when rides are between approximately 2-4 hours. If you're (i) riding for longer than this and/or you know you tend to burn carbohydrates at a high rate, you can aim for slightly higher intakes in the region of 45-60g/hour. You'll know if you tend to burn carbohydrates at a high rate if tend to 'bonk' or 'hit the wall' (run out of energy) towards the end of a Zone 2 endurance ride, or feel you typically need to eat more than others on a group ride.

We don't generally recommend consuming carbohydrates at rates that greatly exceed your individual requirements, because this will tend to shift your metabolism towards carbohydrate rather than fat oxidation, whereas a key goal of endurance rides is typically to improve fat oxidation ability. Thus, consuming excessive carbohydrates can undermine this goal. There are some exceptions to this, however. A key one is if you need to eat during the ride in order to meet your overall energy demands. This might occur if you're riding for most of the day, in which case you won't have much time before/after the ride to make up the calories you've burnt. Other instances where increased carbohydrate intake would be recommended include cyclists who already have a very low body fat, are susceptible to illness, or who have low bone mineral density and/or symptoms of RED-S (see below). In these cases, it's safer to consume higher carbohydrate intakes. Women in the luteal phase of their menstrual cycle may also need to consume carbohydrates at higher rates, as we discuss in Chapter 10.

Group Rides

Group rides are generally more intense than a typical endurance ride, and are usually focussed more on performance and enjoyment than promoting specific adaptations. These rides will likely include high-intensity portions where energy is mainly derived through carbohydrate oxidation. These rides are also often long, meaning you may be at risk of depleting glycogen stores. It's therefore advisable to **ensure you have a carbohydrate-based meal or snack before these sessions, and consume carbohydrates regularly during**. See the table above for guidance on amounts and frequency.

Recovery Rides

These rides are short (generally 60-min or less) and low-intensity, and will be fuelled predominantly by fat oxidation for most people. Accordingly, **there are generally no special nutritional considerations for these sessions**, and you can eat as desired around these sessions.

Resistance Training

Resistance training includes any gym- or home-based session designed to improve muscular strength or power. It usually involves lifting weights, but can also be performed with body weight only or equipment such as resistance bands.

Consuming protein in the post-exercise period helps to stimulate muscle protein synthesis and can enhance strength/power adaptations. Research suggests that, unlike with carbohydrate intake, there’s less urgency in consuming protein in order to optimally trigger these adaptations. Thus, aiming to consume some protein at any convenient point within 2-hours of training is fine.

As discussed in Chapter 4, there’s a limit to the amount of protein the body can process to synthesise and repair tissues within an individual meal. This threshold seems to be roughly 15-25g (or between 0.2-0.3g/kg body weight of high-quality protein). It’s therefore recommended that protein intake is spread across the day in 3-5 smaller meals if looking to optimise adaptations from a resistance training session.

Resistance training can deplete muscle glycogen levels. Therefore, if you’re aiming to do a high-intensity session later in the day after a resistance-training session, then you should also focus on replenishing muscle glycogen by eating 1g/kg body weight of carbohydrates within 30-minutes of the session, and then repeating every few hours until your bike session.

Training with Restricted Carbohydrate Availability

Both elite and amateur cyclists have trained with restricted carbohydrate availability (RCA) for decades, albeit often unintentionally. This training might manifest in the form of early-morning sessions before breakfast, or twice-daily sessions with minimal refuelling in-between.

In both cases, the availability of carbohydrates (in the form of blood glucose and/or glycogen in the liver or muscles) is below baseline. This can impact the energy systems used to produce power, and the adaptations arising from the training.

Often these RCA sessions are borne out of convenience/necessity e.g. enabling workouts to fit around work or family commitments. However, for the last decade or so, there has been mounting evidence to support at least certain types of RCA training as a tool to elicit or enhance certain training adaptations.

More specifically, researchers have been looking at whether RCA training can be used to alter the balance between fat and carbohydrate oxidation at a given workload. There’s now evidence that at least some forms of RCA training may promote adaptations related to improved fat oxidation.

There are two key reasons why you might want to improve your ability to use fats for fuel:

Reason 1: Enhance Endurance

Improving your ability to oxidise fats at a given wattage is useful because it conserves glycogen stores. As a reminder, the average person typically has sufficient glycogen stores to fuel roughly 1.5H of all-out racing. There's also a limit to how quickly you can consume and absorb carbohydrates (~60-120g/hr depending on the type of carbohydrates and how well trained you are at consuming carbohydrates). That's compared with fat stores, which could fuel exercise for days, even for a very lean person.

Improving fat oxidation therefore directly correlates with improved endurance. Better fat oxidation means a better ability to sustain a given sub-maximal wattage for many hours.

Reason 2: Improving Threshold Power

You'll remember from Chapter 1 that there are three main ways that we can produce energy: anaerobic glycolysis (the breakdown of carbohydrates without oxygen), aerobic oxidation of carbohydrates, and the aerobic oxidation of fats[7].

Anaerobic glycolysis and the aerobic oxidation of carbohydrates actually go hand-in-hand in that anaerobic glycolysis is the first step in the aerobic oxidation of carbohydrates. In other words, breaking down carbohydrates to produce energy always starts with an anaerobic phase, and then if enough oxygen is available, is followed up with an aerobic phase.

You'll remember that anaerobic glycolysis results in the production of various metabolites. One of these metabolites is known as 'lactate', and this is a substance that can be measured easily in the blood. Contrary to popular belief, lactate is not itself 'bad', and is actually a very useful fuel source for the body. However, the presence of lactate in the blood correlates with the presence of other metabolites, that have been linked with the onset of fatigue. Lactate is therefore a very good marker for the levels of fatiguing metabolites produced from anaerobic glycolysis.

This has led to the concept of a 'lactate threshold' - a maximum power at which lactate levels (and importantly, the associated fatiguing metabolites) remain constant. Below the lactate threshold, lactate is being produced, but there is enough oxygen available to convert this lactate into more energy, and clear the associated fatiguing metabolites. However, when the threshold is exceeded, the demand for energy exceeds the rate at which oxygen can be supplied, and lactate levels begin to increase exponentially. This correlates with an exponential increase in fatigue.

The concept of 'functional threshold power' or FTP (the maximum power than can be sustained for ~60-mins or in a 40km time trial) is closely linked to the lactate

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[7] Energy can also be produced through other pathways, including direct adenosine triphosphate (ATP) break-down, the phosphocreatine system, and through oxidation of proteins, but these make a comparatively minimal contribution in cycling disciplines, so for the purpose of this discussion we can ignore them.

threshold. They occur at very similar powers, and when the lactate threshold increases, FTP will generally also increase.

The critical point to understand is that, since anaerobic and aerobic carbohydrate metabolism go hand-in-hand, you can't have one without the other. Thus, the greater your tendency to use carbohydrates for fuel, the greater your tendency to produce lactate, and thus the LOWER your lactate threshold or FTP.

In contrast, improving your ability to use fats for fuel, will reduce your production of lactate (and associated fatiguing metabolites) at a given wattage, and will tend to increase the lactate threshold power and FTP. This relationship is illustrated below in Figure 4.

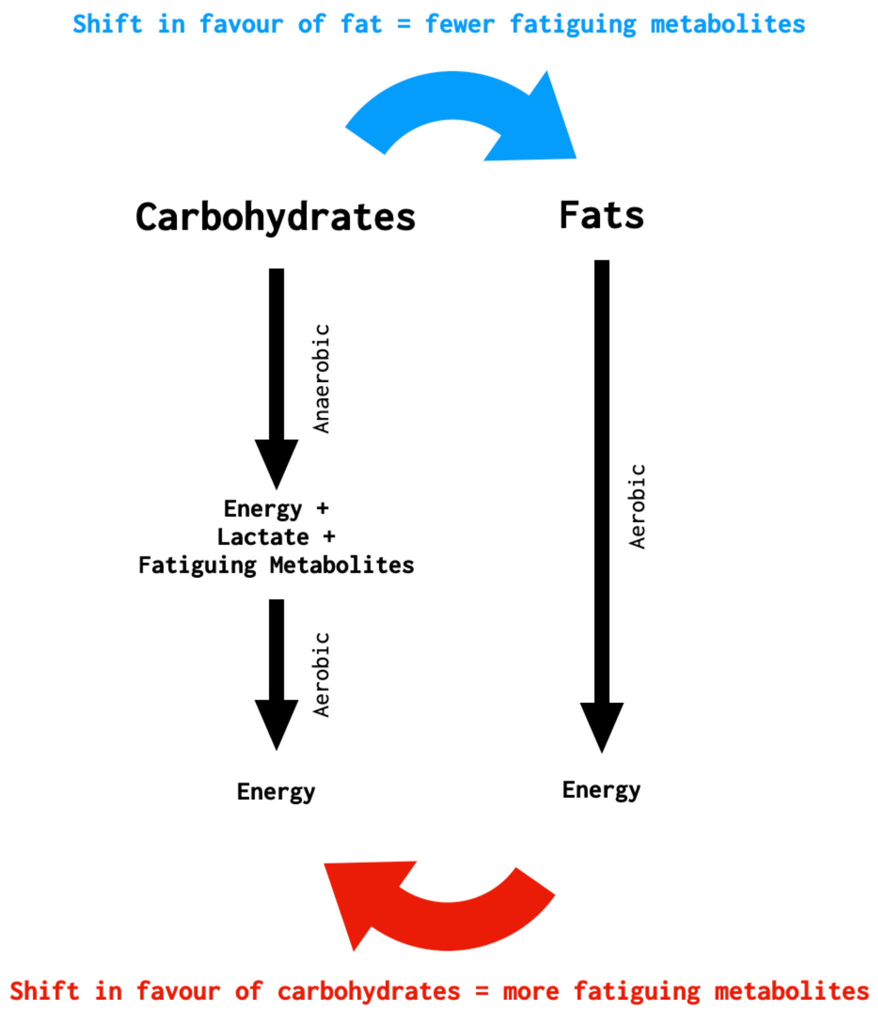

Figure 4. Image showing how the balance between carbohydrate and fat oxidation influences the production of fatiguing metabolites, and thus can impact the lactate threshold/functional threshold power.

Thus, even people competing in relatively short cycling events such as cyclocross, cross-country MTB or crit racing, which do not challenge the body's inherent carbohydrate stores, may benefit from training to develop fat oxidation, because this can help lift FTP/lactate threshold power.

How to Use RCA

There are three main ways to integrate RCA with training:

- The ‘overnight fasting’ method involves training in the morning, before you have eaten or drunk anything that contains any carbohydrate. Liver glycogen stores and blood glucose levels drop gradually overnight, and will usually be below baseline when beginning training in the morning.
- The ‘twice daily’ method involves training twice in one day, consuming minimal carbohydrates between sessions. The first session depletes muscle glycogen stores, meaning the second session is conducted with lowered muscle glycogen levels.
- A combination of the first two methods, which we’ll call the ‘sleep low’ strategy, where the evening before the RCA session, a high-intensity training session is completed which depletes muscle glycogen stores. Carbohydrate intake is then restricted after that session meaning these stores are not replenished. The RCA session is then conducted in the morning after an overnight fast, meaning the RCA session is started with low muscle and liver glycogen and blood glucose levels.

It’s possibly an obvious point, but in all cases, you should avoid eating or drinking carbohydrates during the RCA session.

The evidence supporting the second and third methods is considerably stronger than the evidence supporting the ‘overnight fasting’ method, which is actually quite weak. Nevertheless, there is research that does suggest that overnight fasting might be beneficial over the longer term (e.g. Van Proeyen et al., 2011; Aird et al., 2018), and many cyclists and coaches do use this type of RCA training (either intentionally, or accidentally!) with seemingly good results.

In our view, if you’re really wanting to get the biggest benefits possible from RCA training, we’d recommend either the twice daily or the sleep low strategies. However, if you happen to be training in the morning, and you enjoy doing your sessions fasted, then our view is ‘why not’?! We’ve never seen any evidence that the overnight fasting method will be detrimental, provided you combine this with the right kind of training session and refuel well afterwards. This proviso is important, and we discuss this in more detail below.

So, if it’s convenient to do, then it might be worth including within your training. That said, if you really dislike training in the morning before breakfast, then the evidence is probably not strong enough to warrant using the overnight fasted method.

Suitable Training for RCA Sessions

Nutrition and training are two sides of the same coin. Just in the same way you need to pick the right training intensity to stimulate certain adaptations, you also need to select the right training session to complement carbohydrate restriction.

Much of the early research actually found no performance benefits from RCA training. However, that appears to have been because these studies asked participants to complete all training sessions with RCA, including interval sessions. Intervals are usually heavily fuelled by carbohydrates, and in these studies, participants often could not complete intervals properly with RCA, potentially explaining the lack of performance benefit.

More recent research has looked at using RCA only with lower-intensity training (i.e. below ~85% FTP, 5/10 effort level or 75% Max HR), with positive effects. These training zones are close to an intensity where the fat oxidation system is maximally activated, and thus align with the system we're trying to train with RCA sessions. Furthermore, given that these zones are relatively low-intensity, they can be completed to a high quality despite having RCA.

So, in short, RCA training should only be used with low-intensity training, where the objective is to improve aerobic capacity and fat oxidation/lactate threshold.

How Long to Train with RCA

This really depends on your existing ability to use fats as fuel, and how hard you are riding. We'd recommend starting conservatively, perhaps beginning with 30-60 mins, and building up from there, depending on how you feel.

Some people are able to train for many hours without eating. However, we wouldn't advocate doing RCA training for longer than 2-3 hours, because this will impact your total daily energy and carbohydrate intake (with there being fewer hours in the day when you can actually eat). This may in turn impact subsequent training in the week and increase your risk of illness and injury if you are under-fuelled.

RCA Training Frequency

While there's no scientific research directly looking at this, most researchers and coaches agree that it shouldn't be performed more than twice per week.

Similar to our point above, that's because doing more than two sessions per week might lead to insufficient total energy and carbohydrate intake over the course of the day or week, which might impact your ability to complete subsequent training, and increase your risk of illness or injury.

Carbohydrate-Loading Before a Race

One question that you might be wondering is whether carbohydrate-loading before a race might ‘undo’ the positive changes from RCA training. However, research shows this isn’t the case. Once you have trained for a consistent period with RCA, you should be better adapted at using fats for fuel, even when you are well fuelled with carbohydrates. Unlike with chronically low-carbohydrate diets though (as described in Chapter 4), metabolic flexibility seems to be retained, so that, at higher intensities, carbohydrates can still be used effectively.

Is RCA Training Safe for Females?

Some experts believe that women should avoid carbohydrate-restricted training entirely, as it’s been suggested this can disrupt hormones, and trigger the body to use muscle for fuel (e.g. Sims & Yeager, 2016).

However, these statements generally assume that carbohydrate-restricted training is coupled with high-intensity training and inadequate energy and carbohydrate intake across the day, which causes a high degree of stress.

In our view, provided that carbohydrate-restricted training is used sensibly, meaning you only do this with shorter low-intensity sessions, and you make sure you hit your energy and carbohydrate-intake targets across the day as a whole, then we haven’t seen any clear evidence to suggest it’s unsafe. To our knowledge, there is only one study investigating the use of RCA training in women (and men), under these types of safe and appropriate conditions and over a sustained period (Bennett et al., 2021). This study reported no adverse effects among the female participants (although it’s not clear to what extent adverse effects were monitored!).

Nevertheless, given the potential concerns among females, we’d suggest using RCA training cautiously, perhaps once per week at most, and avoiding this during the luteal phase of the menstrual cycle, where the ability to use carbohydrates is already suppressed. If you don’t feel you’re getting any benefit from this type of training, or are noticing deleterious effects (e.g. a move towards irregular menstrual cycle, irritability, inability to complete training sessions or increased incidence of illness) then we’d recommend avoiding RCA entirely, particularly given that the performance benefits are quite small overall. Of course, this advice applies to men too if detrimental effects are noticed!

As with all training, it’s necessary to cause some level of stress to the body, and we shouldn’t necessarily be afraid of applying stress - the key is to get the balance of stress and recovery right for you as an individual.

Practical Tips for Optimising RCA Training

1. **Take a snack or energy drink with you…** So you can refuel if you need to and/or want to ride for longer.
2. **Have a caffeinated drink before heading out…** Training with RCA can feel harder than training with high carbohydrate availability. Having caffeine around 30-60 mins before can make the session feel a little easier. Just make sure you avoid sugary drinks or adding sugar or milk to tea/coffee.
3. **Avoid RCA during a recovery ride**... That's because the goal of a recovery session is to promote recovery. These sessions should stimulate blood flow to the muscles, without adding any additional training stress or fatigue. That's in conflict with RCA training, which adds an additional training stress.
4. **Avoid RCA if you are ill…** That's because limiting carbohydrates can compromise your immune system, and might mean it takes longer for your illness to clear.
5. **Make sure you refuel well afterwards…** Training fasted can acutely induce a fairly large energy deficit, where you are burning considerably more calories than you are consuming, particularly if your ride is quite long. However, this is something we generally want to avoid over the longer term (e.g. over a period of several days). We want to ensure you are taking on enough fuel to adapt to the training, and to perform your high-intensity training sessions well. We therefore recommend making sure you consume a meal or snack that's high in carbohydrates within 30-minutes of finishing your RCA ride. This is the period of time in which your muscles will be most receptive to carbohydrates, helping to replenish your muscle glycogen stores more effectively. Thereafter, eating carbohydrates every few hours will further speed up glycogen replenishment and help meet your daily energy demands.

Training the Gut

Having considered the benefits of training with limited carbohydrate availability in low-intensity endurance rides, it's also worth mentioning that there can be a benefit to completing at least some of your longer endurance rides with high carbohydrate intakes, in order to 'train the gut' to absorb carbohydrates faster and reduce the risk of stomach discomfort.

Although in theory, carbohydrates can be absorbed from the small intestine at a rate of 90-120g/hour (depending on the specific combination of carbohydrates), in practice many people can often only take on carbohydrates of a rate of up to ~60g/hour without specific gut training.

Consuming high intakes of carbohydrates, either across the day more generally, or within training sessions, have been shown to increase the number of carbohydrate-specific transporters within the small intestine.

There’s still quite minimal evidence to help guide optimal ‘gut training’ practices. However, it seems that adaptations can occur quite quickly (such as in response to just 3 days of increased carbohydrate intake).

It’s also good to practice your specific race nutrition strategy in training, to make sure your food choices are agreeable, and that regular fuelling and hydration becomes second-nature. So, this is another key benefit of performing some training sessions with high carbohydrate intakes.

We like to integrate race-like carbohydrate intakes during the specific preparation phase of training (i.e. 1-2 months away from major competition), and particularly during any session that closely replicates the demands of competition. This gives the best chance of determining whether a particular nutrition strategy will be successful (both in terms of practical considerations, and gut health!), as well as an opportunity to help train the gut to take on high rates of carbohydrates under race-like conditions.

Chapter Summary

- The timing of nutrients shortly before, during and after a training session can help or hinder execution of your session, and the adaptations that result. In this chapter we set our key recommendations for different types of session.
- Training with restricted carbohydrate availability is often advocated in cycling. Evidence that simply training fasted helps improve aerobic adaptations is not clear, and the best evidence is for the ‘sleep low’ and ‘twice daily’ strategies. However, even in these cases, the performance benefit is probably only quite small, so we only recommend using this strategy if you enjoy it, and it should only be used in conjunction with low and middle intensity sessions (<~85% FTP, 5/10 effort level or 75% Max HR). There’s a risk of under-fuelling and under-training with this strategy, and so it should be used with caution.
- In order to take on high amounts of carbohydrates during races, you may need to spend some time ‘training the gut’, which can involve eating high carbohydrate intakes across the day, or practicing high carbohydrate intakes in training.

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Chapter 6: Weight Loss

Reducing body weight, or more specifically body fat, can sometimes help improve cycling performance, particularly on hilly courses.

In this chapter, we'll cover everything you need to know to implement a safe, sustainable, and successful weight loss strategy alongside your training.

Strive for a Weight that Optimises Performance

Before diving in, it's important to reinforce that although being lighter can be favourable, most people will have an 'optimal' competition body weight, which may not necessarily be the lightest weight they can physically achieve. Indeed, as should be very clear from the preceding chapters so far, nutrition has a key role in supporting training. If this is restricted too much, training and the associated adaptations can be hampered to such an extent that the reduced body weight does not make up for the negative impact on fitness, health and performance.

In essence, lighter isn't always better, and a **healthy** weight that allows you to perform training well, avoid illness or injury should always be the primary goal.

Generally, a healthy and sustainable (but still competitively light) body fat for men is between 6-12%, and for women between 12-20% (with younger cyclists erring on the lower end of this spectrum, and older cyclists erring on the higher end). However, some cyclists may find they perform better with a higher percentage body fat, and that's absolutely fine. There are many top-level cyclists who have found this to be the case, and written about it extensively, particularly among female cyclists. Evie Richards, multiple-time XCO World Champion and Commonwealth Gold medallist, is a great example.

We recommend using your past experiences to help guide you on your optimum weight. For example, some indications that you may have dropped below your optimum weight or body fat percentage include: a drop in energy levels or training motivation, an increase in the rate of 'failed' training sessions (i.e. sessions that you were previously able to complete, but which you can no longer tolerate), an increased frequency and/or duration of illness, or (among women) a disruption to the menstrual cycle.

Energy Deficiency

Related to the point above, it's also very important to highlight that a sustained energy deficiency can be very harmful to health.

In endurance sports, and particularly cycling, a syndrome known as ‘Relative Energy Deficiency in Sport (or RED-S for short) is quite common, due to the high training volumes and associated high energy demands. This is compounded by the common focus on achieving low body weights to improve watts per kg.

RED-S is a syndrome that can affect both men and women, leading to weakened bones, missed or irregular periods, disturbed endocrine, metabolic, cardiovascular and gastrointestinal health, reduced immunity and phycological problems. From a performance perspective, RED-S can have a negative effect on endurance, injury risk, training adaptations, mood, and muscle strength.

Some readers may be familiar with the term ‘Female Athlete Triad’, which was the first recognition of this syndrome (initially identified in females only). However, the newer terminology of ‘RED-S’ now recognises a wider array of symptoms, and the fact that these symptoms affect men as well as women.

The syndrome arises when energy intake is not sufficient to meet the demands of regular bodily processes, and these processes then become suppressed.

To understand this better, we can consider the concept of ’energy availability’. This is the amount of energy that you have left after all exercise-related expenditure has been subtracted.

So, for example, if you consume 2500 kcals, and complete a ride that burns 500 kcals, then your energy availability is 2000 kcals. This is the amount of energy that you have available to fuel all other metabolic processes throughout the day.

Research suggests that for optimal health and weight maintenance, an energy availability of 45 kcals per kg of fat free body mass is needed. It’s ok to step slightly below this if you’re looking to lose weight. However, there is a tipping point for energy availability, below which, bodily processes become suppressed and the RED-S symptoms become apparent. This tipping point has been estimated to be 30 kcal per kg of fat free body mass in women.

So, for example, if we have an athlete who weighs 60kg, and they have 18% body fat, then their fat free mass is 49.2kg. This means that they need to consume an absolute minimum of 1,476 kcal per day, plus any energy they expend on the bike and during other exercise through the day (e.g. walking, strength training etc.).

Less evidence exists in relation to the tipping point for men, but it’s been suggested the threshold may be slightly lower.

It’s worth noting that weight loss isn’t a necessary condition of having inadequate energy availability. If bodily processes become suppressed, then it’s possible to have an energy availability below the 30 kcals/kg limit, without any weight loss. It’s therefore important to pay attention to the signs and symptoms of RED-S, particularly missed or irregular periods, low mood, irritability, frequent illness, and multiple bone breaks/fractures.

Safe Rates of Weight Loss

Another important thing to understand is that weight loss should be a slow and gradual process. This is not only because aiming for rapid weight loss will compromise your ability to train and may result in loss of muscle mass, but also because rapid weight loss can kick off the above-mentioned energy-conserving processes, and increase the risk of developing RED-S. This metabolic suppression doesn't immediately reverse once you stop restricting food intake, which then makes it harder to maintain any weight loss. This is one of the key reasons ‘crash’ dieters typically lose weight and then put more weight back on when they revert to their previous eating patterns, effectively gaining weight over the long term.

A safe rate of weight loss is around 1 lb or just under 0.5 kg per week which corresponds to an energy deficit of approximately 500 kcal per day. If you have enough time, then aiming for an even smaller deficit, and slower rate of weight loss would be more preferable, as this will give you the best chance of maintaining good training, health and muscle mass (e.g. a 250 kcal/day deficit, which should achieve half a pound per week).

In females, a good sign that weight loss is proceeding at a safe rate is the maintenance of menstrual function. In all athletes, we’d also recommend monitoring mood, training motivation, and the ability to perform high-intensity sessions. If any of these are compromised, this can be an indication that the rate of weight loss is too high.

Planning for Weight Loss

Pulling everything above together, the key to a successful weight loss strategy is to set a realistic weight loss goal, and to start working towards this goal at an appropriate time.

Much like planning your training, you’ll need to work back from your target event to determine how much weight it’s realistic to lose, and when you might want to start this process. Indeed, we think it’s good practice to include any planned weight-loss within your high-level training plan, so that you can make sure the timing of this weight loss is compatible with your training and competition plans.

It’s generally recommended that weight loss is best achieved through the base training phase (i.e. when competition is generally 3-6 months away), where training volume is generally high and there is less high-intensity training. This has the benefit that (i) an energy deficit is easier to achieve due to high training volumes and (ii) any potential suppression in the ability to complete high-intensity training due to reduced energy availability and/or glycogen stores will be less detrimental to the training as a whole. However, the disadvantage of this approach is that a lowered body weight then needs to be maintained through the rest of the season.

In our view, it’s often better to have a phased approach to weight loss. During the base phase, the goal might be to get down to a weight that’s within perhaps 1-2 kg of your competition weight. This should be a weight that’s sustainable without too much trouble and/or impact on your regular eating, training and lifestyle over the subsequent months leading up to competition.

Then closer to the start of the race season or A-priority event, a second weight loss phase can be implemented over a period of 3-6 weeks with a very small energy deficit (e.g. 250 kcal/day) to help reach the target weight in time for competition.

Exactly when these phases fall should ideally be considered alongside your training plan, to minimise the risk that training is compromised by restrictive energy intake. For example, if you’re planning an ‘overload’ training week with an increase in your usual volume of high-intensity training, then this may not be a good week to be also aiming for weight loss.

Creating an Energy Deficit

To achieve an energy deficit while supporting training, we’d generally recommend cutting down primarily on fat intake, so that this sits closer to 20% total energy intake. This is because, provided your fat intake meets the minimum requirements to support key bodily functions such as hormone production and building of cell membranes and other structures, then cutting down on fat intake doesn’t generally hinder training or performance.

You can also aim for slightly lower carbohydrate intake than your usual carbohydrate intake, particularly on certain days where carbohydrates are less critical (see next section below).

In contrast to fats and carbohydrates, which can be slightly reduced, we’d recommend making sure your protein intake is relatively high. Ideally this should be in the region of 1.8-2.3g per kg of body mass per day. Protein is very satiating, so it helps to keep you feeling fuller for longer, and high intakes of protein also help conserve muscle mass while in a calorie deficit.

In addition to these main guidelines, some practical steps to help you achieve an energy deficit, and to enjoy the process are outlined below:

1. Take a critical look at your current diet and consider keeping a diet diary for a few days. Often there are a few simple things you can change to help cut out 100-500 kcal/day without really noticing it. Some key examples would be switching to diet soft drinks, reducing alcohol, switching to low fat varieties of meat, dairy, sauces and dressings, reducing condiment portion sizes (e.g. mayo, ketchup), switching from a latte/cappuccino to an Americano, and so on.
2. While an energy deficit will largely be achieved through diet, consider integrating some additional low-intensity exercise to help contribute towards your deficit target. For example, a few miles of walking each day or low-intensity riding will add to your daily calorie expenditure without having a meaningful impact on fatigue levels.
3. Don't go all-or-nothing. There are no 'bad foods'. Don't cut anything out entirely, as this isn't sustainable, and you're liable to 'fall off the bandwagon' and binge on foods that you've restricted. Instead, try to use your indulgent foods in a functional way. If chocolate is your vice, for example, then use this as part of your ride fuel on the bike.
4. You shouldn't be eating smaller volumes of food just because you're cutting down on calories. Instead use vegetables to bulk up your meals. Aim for at least half of the volume of each meal to be made up of vegetables. These are filling, due to their high fibre content, and very low in calories.
5. Try to time meals and training so that your regular meals fall at convenient points around training. This means there's less need for additional training-related snacks.
6. Try to plan ahead if travelling or away from home to avoid having to rely on suboptimal meals. Take meals and snacks with you, rather than having to eat out.
7. Many people skip breakfast as a means to induce a calorie deficit. While this can work for some, in many people, it can actually lead to higher energy intake overall. This is because it may cause you to snack more on energy-dense foods later in the day. If you want to try skipping breakfast then be mindful of this, and if you notice yourself snacking more than you did before, then perhaps breakfast-skipping isn't for you!
8. Keep foods that you're liable to unintentionally snack on out of sight, and away in cupboards. A key example is breakfast cereal, which many people keep out on the worktop. It's very easy to mindlessly grab a handful of when you're passing by, and you might not even notice you're doing it. Over the day these little snacks can add up to quite a considerable number of calories.

Integrating Weight Loss Alongside Training

As we've already discussed, it's now widely recommended to periodise nutrition to suit the demands and goals of a given training session. The same is true for weight loss, and we've set out below some guidelines on how we'd recommend integrating weight loss while still supporting training.

Interval Sessions/Group Rides

With these sessions, we think that nutrition in the 2-4H before is the most important thing to focus on; aiming to get in 1-2g/kg body weight carbohydrates within that window, so that you can perform well and sustain high intensities where required.
It can be good to try to time your meals and training sessions, so that you have a main meal falling within that 2-4H window, rather than needing to have an additional snack beforehand.

Outside that window, you're safe to cut carbs/energy intake. In particular, given that the next training day is likely to be either an endurance ride or a recovery day, then getting a recovery meal/snack in right after your interval session is not critical.

Endurance Rides

As we've discussed previously, there can be a benefit in doing these sessions with restricted carbohydrate availability. Thus, days where you have an endurance ride planned can be good ones for cutting down on carbohydrate and energy intake overall. On these days, we suggest aiming for 3-6g of carbohydrate per kg body weight across the whole day, depending on overall energy needs.

For shorter endurance rides (1.5H or less), we also don't think there's an urgent need to get a recovery meal in right after your ride, so you can just wait until your next normal meal or snack, and this doesn't necessarily need to be particularly high in carbohydrates, as the session probably won't have impacted your glycogen stores very much.

For longer endurance rides (>1.5-hours), particularly if done with restricted carbohydrate availability, we do think it's more important to eat a carbohydrate-based meal/snack shortly afterwards, because your glycogen stores are likely to be quite low. You don't want to spend excessively long with low glycogen levels as this can negatively impact immunity.

So, in summary, for endurance rides, carbohydrate intake can be relatively low before and during a ride (relative to our standard recommendations in Chapter 5). However, if the ride is long, we'd suggest making sure you get a decent carbohydrate-based meal/snack after.

Recovery Days

Although your energy expenditure is likely to be lower on a recovery day, we wouldn't recommend overly restricting energy intake on these days, because this is where most of your training adaptations will take place, and we don't want these to be impaired by having inadequate energy availability.

On these days, it's probably best to aim for just a modest energy deficit of around 100-200 kcal.

This is also a good day for focussing on consuming regular portions of protein to help with muscle repair etc. These don't need to be large portions - as mentioned above there's an upper limit on the amount of protein the body can process for muscle protein synthesis within a single meal. A good target is ~4 portions of protein spread across the day, each containing around 15-25g of protein (~0.2-0.3g/kg body weight).

Monitoring Body Composition

In order to determine the success of any weight loss strategy, it's important to monitor body composition.

The most common method is simply to measure body weight. However, as a cyclist, you'll generally be wanting to specifically target a reduction in body fat, while maintaining or even increasing your muscle mass.

That being the case, we'd strongly recommend taking an approach that allows you to track changes in your body fat levels specifically.

There are several ways this can be done, but the most accessible method is to buy a set of 'bioelectrical impedance' scales. These scales send a low-level electrical current through your body (don't worry, this is safe and painless!). The length of time taken for the current to travel through your body allows the algorithms in the scales to determine percentage body fat and 'fat free mass' (i.e. the weight of everything else in your body other than fat, which includes muscles, ligaments and bones for example)[8]. 'Tanita' is a well-known and reliable brand of bioelectrical impedance scales. They manufacture devices that are used in laboratory and medical settings, but also have a range of home-based scales.

The most accurate bioelectrical impedance scales have electrodes both at the feet, and at the hands. This allows the current to run through your whole body. Cheaper bioelectrical impedance scales just have electrodes at the feet, and with these, the current runs only through the lower part of the body.

To get reliable measures from your bioelectrical impedance scales, we recommend the following:
- Take measures at the same time every day (ideally first thing in the morning, before eating or drinking).
- Try to urinate before weighing yourself.
- Try to maintain a consistent hydration level when taking your measurements.

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[8] Some devices also estimate muscle mass, total body water and sometimes other variables, such as basal metabolic rate.

• Weigh yourself with minimal clothing.

Even when using bioelectrical impedance scales rather than ordinary scales, there are still some factors that will lead to day-to-day variation in your body weight and your percentage body fat estimate. In particular, differences in hydration levels, and the levels of glycogen stored in your muscles will impact your measures. Changes in hormone levels for menstruating females will also impact results, with fluid levels and body weight being higher in the 1-2 weeks leading into a period.

These factors should all be considered when measuring your weight and body fat, and it's important not to get disheartened by day-to-day variations, as they could simply reflect changes in muscle glycogen levels, or fluid retention. Indeed, it's best to look at trends over a period of at least two weeks, and ideally longer to reliably determine how your body composition is changing.

An alternative method for monitoring body fat is to have 'skin fold' measures taken. This involves visiting a qualified practitioner, who will use a set of skin fold callipers to measure the thickness of your skin and subcutaneous fat at various standardised sites across the body. They will then usually provide a total 'sum of skin folds' measure (i.e. the total thickness of your skin and subcutaneous fat across all the measured sites), and an estimated percentage body fat.

If you opt to go for skin folds measures, then make sure you use an appropriately qualified practitioner, because measuring skin fold thickness requires comprehensive training to reliably identify the measurement sites across the body and to measure the skin folds accurately. The International Society for the Advancement of Kinanthropometry (ISAK) has developed international standards for training and accreditation of practitioners, and we would recommend making sure anybody you use us ISAK accredited, if possible.

Chapter Summary

• Although being lighter can be favourable for many cycling disciplines/events, most people will have an 'optimal' competition body weight, which may not necessarily be the lightest weight they can physically achieve.
• Generally-speaking, a healthy and sustainable body fat for men is between 6-12%, and for women between 12-20%. However, some cyclists may find they perform better with a higher percentage body fat levels.
• In endurance sports, and particularly cycling, a syndrome known as 'Relative Energy Deficiency in Sport (or RED-S for short) is quite common. This is a syndrome leading to weakened bones, missed or irregular periods, disturbed endocrine, metabolic, cardiovascular and gastrointestinal health, reduced immunity and phycological problems. From a performance perspective, RED-S can have a negative effect on endurance, injury risk, training adaptations, mood, and muscle strength.

- A maximum safe rate of weight loss is around 1 lb or just under 0.5 kg per week which corresponds to an energy deficit of approximately 500 kcal per day.
- Energy availability is the amount of energy you consume in a day minus the amount of energy you've burnt in training, and corresponds to the amount of energy available to support essential bodily functions and day-to-day life. Care should be taken to avoid dropping below an energy availability of 30 kcal per kg of fat free mass, as this can lead to suppression of key bodily functions and development of RED-S.

Chapter References

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Chapter 7: Hydration

Keeping adequately hydrated is important for most cycling disciplines. Water typically makes up around 60% of total body weight, and is essential for the proper functioning of muscles, central nervous system, and the circulatory system, including the supply of oxygen to the muscles, and the removal of metabolic waste products.

During exercise, the biggest source of fluid loss is through sweat, although some is also lost through other routes, such as respiration (i.e. water vapour in breath), and excretion through urine and faeces.

How Much Fluid Loss is Ok?

During most endurance races, at least some degree of dehydration is inevitable, as it’s hard to drink sufficient fluids to completely replace all fluid losses, particularly in more intense and/or technical races. Moreover, for some hilly courses, it’s possible that a small level of dehydration might be performance-enhancing, due to the reduction in body weight. In this section, we’ll therefore consider whether some degree of dehydration is acceptable under certain scenarios.

In the sports nutrition field, it’s widely accepted that fluid losses amounting to 2% body weight consistently impair performance in endurance athletes, when competing in environments of approximately ~20°C and above, and when at altitude. The warmer the environment, the greater the performance degradation due to dehydration. Dehydration of around 3% body weight has been shown to reduce power output/work done by around 3% on average, based on pooled data from a range of studies and sports. However, these conclusions have been based, at least in part, on some older hydration studies, which have various flaws (such as inducing dehydration through heat exposure, not blinding participants to which trial they are on, and so on). It’s therefore possible that these ‘confounding’ factors may have impacted performance independently of actual hydration status.

When we look specifically at cycling-related literature, and only at studies that are better designed to avoid those confounding influences, the data are less clear-cut. For example, a ‘meta-analysis’ pooling data from 5 studies looking at the impact of dehydration on cycling time trial performance found cyclists were able to tolerate up to 4% dehydration without a detectable impact on performance (Goulet, 2011). The average temperature across the studies was 26.0±6.7°C and average time trial duration was 86±34 min. This ‘meta-analysis’ study is particularly compelling, because in all of the reviewed studies, dehydration was induced during the exercise test, rather than beforehand, and is therefore more closely aligned to real-world racing conditions.

Other, more recent and well-designed cycling studies have also corroborated the earlier findings of Goulet, including a study showing 4% body mass loss doesn’t impact short

5km cycling time trial performance at 18-25°C (Stewart et al., 2014), and a study indicating that 3% body weight loss has no impact on 25km time trial performance, when riding at 33°C and a wind speed of 32km/hour (Wall et al., 2015).

Despite the above, it's clear than under certain conditions, such as very high environmental temperatures, performance is still impaired by relatively low levels of dehydration. For example, in another well-controlled study, Adams et al. (2018) found that performance in a 5km time trial completed immediately after 2-hours of riding at 55% $\dot{V}O_{2max}$ (roughly 60-70% FTP) was impaired by dehydration of just 2% body weight when riding at 35°C.

Pulling everything together, it seems that under many real-world racing scenarios, provided the environmental temperature is not particularly hot (e.g. <25-26°C), then slightly more than 2% dehydration can be tolerated without performance decline. This is something worth bearing in mind if you're completing a hilly course, and it might be prudent to take a more conservative hydration strategy and allow perhaps up to 2-3% dehydration in such events.

However, in longer and/or hotter events, and perhaps those with less air cooling, dehydration of around 2% may still be detrimental. For these events, then a more aggressive hydration strategy is probably advisable.

Monitoring Hydration Status and Sweat Rates

There are two key methods that can be used to monitor hydration status without having access to a lab.

The first is to monitor body weight. This can be achieved by:

1. Weighing yourself immediately before you ride, with no/minimal clothing on, and after urinating.
2. Monitoring your fluid intake during your ride.
3. Weighing yourself immediately after your ride, with no/minimal clothing on, and after urinating and having dried your skin of any sweat.
4. Calculating your body mass loss in kg. This tells you your hydration status. For example, if you weighed 60kg before your ride, and 58kg after the ride, then you lost 2kg or 3% body weight due to dehydration.
5. You can then calculate your sweat loss by adding your body mass loss (where 1kg = 1L) to the amount of fluid drunk. This will tell you your sweat loss. For example, if you determine you've lost 2kg in body weight (i.e. 2L), and also drank 1L of fluid, then your total sweat loss was 3L. If you were riding for 3-hours, you can determine that your sweat loss rate was 1L/hour.

It's useful to monitor your sweat rates under various environmental conditions, so that you get an idea of how much you may need to drink under different conditions. Some key conditions to be aware of include (i) hot weather above 25-28°C (ii) mild environments around 18-22°C and (iii) cold environments of around 5-10°C. With cold environment, you may find that sweat rates are higher than anticipated, due to the type of clothing worn, which can be less breathable.

Another approach to assessing hydration status, and one that can be particularly useful before a race or event if to monitor your urine colour in the toilet bowl. If your urine colour is light (like lemonade or light beer) then you are hydrated. Broadly-speaking you should be aiming to keep your urine colour within the spectrum shown below. If your urine colour is darker than this, then this is a strong sign that you're dehydrated.

Figure 5. Urine colour spectrum for hydrated person. Shades darker than these indicate dehydration.

Electrolytes/Sports Drinks

The electrolytes sodium, potassium, calcium and magnesium are lost through sweat. These minerals fulfil many roles in the body. In relation to cycling, they are important for the proper functioning of the muscles and nerves and maintenance of blood volume, which is central to regulating body temperature. Although muscle cramps are usually linked to muscle fatigue, there is also some evidence that electrolyte imbalances can sometimes bring on cramping. Sodium is the most notable electrolyte lost in sweat (which is why sweat tastes salty!).

Including electrolytes and particularly sodium within drinks is recommended during exercise, especially if you know you are a heavy-sweater, or a 'salty sweater'. You'll know you're a 'salty sweater' if you tend to see lots of salt residue on your helmet and clothes, and struggle with sweat stinging your eyes. Electrolytes are also recommended if your ride or event is likely to last longer than roughly 2-hours, because the cumulative electrolyte losses may be quite high. Electrolytes also help to retain fluids that have been consumed, helping to hydrate more effectively.

Electrolytes can generally be found in stand-alone 'electrolyte tablets', which typically contain no or very low amounts of carbohydrate, and can be found in different electrolyte 'strengths' so that you can match these to the saltiness of your sweat.

They can also be found in gels and energy drinks. Eating salty foods, such as crisps or salted nuts is another way to help replace electrolyte losses, and one that might be preferred in long events like ultra-distance races. Overall, you should aim for between 125-750mg of sodium per hour, depending on sweat rate and sweat ‘saltiness’.

It’s also possible to make homemade electrolyte drinks by mixing 600ml of water with around 1/16 teaspoon of salt, and around 1tsp of sugar-based sweetener (e.g. sugar, maple syrup, honey etc.). Add lemon, lime, mint, sugar-free cordial or other flavourings of your choice, if you wish!

Hyponatremia

Hyponatremia is a condition that can develop during exercise, where the sodium content of the blood falls below 135 mmol/L. Risk factors for developing hyponatremia include excessive drinking, and inadequate sodium replenishment. When at rest, any excess fluids are simply excreted via the kidneys. However, during exercise this process doesn’t always function correctly.

The symptoms of hyponatremia are concerningly similar to those of dehydration (e.g. nausea/vomiting, headache, confusion, and fatigue). In the worst cases, it can lead to seizures, coma or even death. It’s therefore important to be aware of this condition, because if hyponatremia is incorrectly diagnosed as dehydration, and further fluids are ingested, then this can exacerbate the problem.

It’s worth being aware that women are at increased risk of developing hyponatremia, due to their lower body size and sweat rates. Hyponatremia is also more commonly found among slower cyclists and/or in longer events, where competitors are not losing as much fluid through sweat, and there’s a heightened risk of over-drinking.

Carbohydrates in Drinks

Whether or not to include carbohydrates in your drink is a contentious topic.

Although energy drinks are often a convenient way to take onboard carbohydrates during a race, they can present two digestive problems. Firstly, they can slow down the rate of ‘gastric emptying’ (i.e. the rate at which fluids exit the stomach and enter the small intestine). This means a delay in the supply of both fluids and carbohydrates to the body, and an increased risk of stomach problems such as cramps or nausea.

Secondly, once the fluids have entered the small intestine, the high carbohydrate content can slow the rate of absorption of fluids into the bloodstream, due to the high osmolality (i.e. concentration) of the fluids. If energy drinks are particularly strong, they can even cause fluids to be pulled from the blood into the small intestine to reduce the osmolality of the fluid. This can exacerbate any dehydration, and can trigger severe stomach discomfort.

Carbohydrate-containing drinks can be particularly problematic in the heat, due to slower gastric emptying rates induced by the heat, coupled with increased fluid requirements.

There are three main types of energy drink to be aware of:
- **Hypotonic drinks**. These have a low concentration of carbohydrate, where the total concentration of solute dissolved in the drink is lower than the concentration of solute found in the blood. These drinks generally contain 4g per 100ml of carbohydrates or less (i.e. <3% solution)
- **Isotonic drinks**. These have a very similar concentration of solute dissolved in the drink relative to the concentration of solute found in the blood. They usually contain between 4-8g per 100ml of carbohydrates (a 4-6% solution).
- **Hypertonic drinks**. These have a higher concentration of solute dissolved in the drink relative to the concentration of solute found in the blood. They typically contain between >8-10g per 100ml of carbohydrates (i.e. > 8-10% solution).

Generally-speaking, hypertonic drinks should be avoided, as these have the highest risk of causing stomach problems.

Isotonic drinks can usually be used safely. However, bear in mind that if you’re also consuming other energy-containing foods, these can increase the energy content and osmolality of the liquid in your stomach, and therefore may still trigger gastrointestinal issues.

If you’re mixing different types of energy sources (e.g. gels, bars, energy drinks and real food), then the safest option is often hypotonic drinks (or indeed plain water or energy-free electrolyte drink). This will give the lowest risk of experiencing stomach issues.

Drinks containing ‘alginate hydrogels’ have received attention recently as a potential means to speed up gastric emptying. However, the evidence to support their use is not yet conclusive. Nevertheless, you’ll still see some sports nutrition products on the market containing hydrogels (e.g. Maurten gels).

It’s worth noting that energy gels behave in a similar way to sports drinks once they mix with fluids in the stomach, and therefore should also be considered when working out your carbohydrate concentration, and associated gastrointestinal risks!

Race Hydration Strategies

Fluids Before a Race

The hydration strategy you take before beginning a race will depend on the characteristics of that race. For longer endurance events, where fluid losses are likely to cumulate over many hours, and/or events where body weight isn't a critical factor (e.g. a flat time trial), then you'll want to start a race well hydrated. This can be achieved by drinking 5 to 10 mL/kg body weight over the 2-4 hours before competition. Sodium/electrolytes (e.g. 200mg per 500ml) can be added to the fluid to aid with fluid retention. If you're competing in a hot environment, then drinking cold drinks can also help to reduce your core body temperature, and can provide a boost to performance.

If, on the other hand, you're competing in a short event, where body weight is highly determinative, and particularly if the environment is cold, then it may be advantageous to slightly restrict fluid intake before a race and start the race in a slightly (but not excessively) dehydrated state.

A key example would be a short hill climb time-trial, where maintaining a low body weight is a key performance determinant, and where a small level of dehydration (e.g. 2-3% body weight) is unlikely to negatively impact power output, particularly if the weather is cold.

We don't recommend following any aggressive strategies in order to achieve a dehydrated state (e.g. use of a sauna), as this might negatively impact performance, and may lead to a more extreme level of dehydration than is safe/advantageous. However, it's probably advisable to be mindful of fluids taken on over the ~4-hours leading into a race and only drink small amounts when you feel the need. You may also want to limit sodium intake over the 24-hours leading into a race to help reduce water retention.

Fluids During a Race

Rates of fluid loss vary between 0.3 to 2.4 L/h depending on individual characteristics, exercise intensity, duration, heat acclimatisation, altitude, and other environmental conditions. Altitude and higher temperatures and/or humidity tend to elevate fluid losses. There can also be considerable fluid losses in very cold environments due to the insulating clothing worn and respiratory losses. This is exacerbated by the fact that thirst sensation is typically suppressed in cold weather. It's therefore not possible to give any firm recommendations as to how much you should drink.

Strategies for hydrating during an event are also quite contentious. Some experts recommending drinking to 'stay ahead' of thirst, basing fluid intake rates on knowledge of your sweat rate under various circumstances, and drinking before the point that you feel thirsty.

Other experts suggest that drinking to thirst (i.e. only when you feel the urge to drink) is preferable because this helps avoid the risk of over-drinking, which can lead to hyponatremia. Moreover, some studies have even shown that drinking to thirst provides a performance benefit when compared to drinking to replace all fluid losses (Goulet, 2011).

Our take on things is that, since the literature suggests that relatively high levels of dehydration can be tolerated in cycling, then drinking to thirst is probably best for most events. However, if the weather is hot, and/or you expect to have considerable fluid losses over the course of a race, then it might be wise to aim to stay a little ahead of thirst, and to plan to drink enough to mostly meet your expected fluid losses. Most people can tolerate drinking between 0.4-0.8L/hour without gastrointestinal issues.

It’s worth noting that some events are so short and/or intense, that it’s very hard to drink during an event (e.g. short hill climbs). For these types of events, fluid losses will be minimal, simply as a result of the short race duration, and hydrating during an event needn’t be a consideration.

Fluids After a Race

The most effective way to rehydrate after an event is to drink fluids little and often over a period of 2-4 hours. Avoid drinking large amounts of fluid quickly, because this will cause more of the fluid to be excreted through the kidneys. You can also add some sodium to your fluids (e.g. 200mg sodium per 500ml fluid) to aid with fluid retention. Sodium taken in through foods will also serve the same purpose.

If you are competing in a stage race or ultra-distance race, and need to rehydrate properly for the next day/race, then it’s important to avoid alcohol, as this acts as a diuretic, and promotes fluid loss.

Chapter Summary

- When riding in hot and/or humid environments, then dehydration of 2% body weight or more can significantly impair performance. However, it seems that under real-world conditions cyclists can tolerate slightly higher levels of dehydration than previously thought in more temperate environments (e.g. <25-26°C).
- The electrolytes sodium, potassium and calcium are lost through sweat and often need to be replaced during exercise, in order to maintain effective nerve and muscle function, and blood volume. Electrolytes are particularly recommended for heavy/salty sweaters and if exercise lasts longer than 2-hours.
- Hyponatremia is a condition where the sodium content of the blood falls below 135 mmol/L. It can be brought on by excessive drinking, and inadequate sodium

replenishment. The symptoms are very similar to dehydration. Women and slower riders are particularly at risk due to lower sweat rates.

- If using energy drinks, make sure these are either isotonic or hypotonic (i.e. less than or equal to the concentration of solutes in the blood).
- Your hydration strategy before a race should consider the length of the race and the environment, where certain short races in cooler conditions may benefit from slightly limiting (but not completely excluding) fluid and sodium intake in the hours leading into the race in order to reduce body weight.
- During an event, the best advice is generally to drink whenever you have the urge. However, in hot environments, and if you are a heavy sweater, then it may be better to aim to stay slightly ahead of thirst.

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Chapter 8: Nutrition for Racing

Unlike training nutrition, where the main goals are to enable a planned session to be performed as intended and support and/or enhance training adaptations, the primary goal of racing nutrition is simply to maximise performance. This means that a different nutritional approach is often needed for racing, as compared to training.

Nutrition to enhance performance typically centres on:
1. Ensuring fuel availability and hydration status is optimal (considering the demands of the event, alongside concerns such as minimising body weight).
2. Avoiding gastrointestinal problems such as nausea, stomach cramps or diarrhoea.
3. Considering the risks versus benefits of any performance-enhancing (or so-called ‘ergogenic’) supplements.
4. Devising a practically-implementable nutritional strategy given the constraints of a particular race.

Within the supplementary materials for this guide, we have a series of one-page ‘cheat-sheets’ outlining the recommended nutrition strategy for various types of event. These can be printed out if you wish. In this chapter we outline the theory and rationale behind these recommendations for those interested, and give some practical tips, such as how to manage nerves and associated loss of appetite.

Test Your Race Nutrition!

The first, and most important point to make when it comes to race nutrition is to **test your race nutrition strategy** in training, and low-priority races! By far the biggest potential impact of nutrition on your race/event is if you happen to experience gastrointestinal problems. You need to be absolutely sure that any foods, drinks and supplements you consume both shortly before, and during your event are tolerable and don’t cause you any issues.

This is something to consider in particular if you plan to use foods/drinks provided at feed stations during your event, and we’d recommend finding out what’s available ahead of time and testing these items out in training before you use them.

You’ll ideally want to test your nutrition at a race-like intensity, and (if possible!) under similar environmental conditions you expect on race day. During the specific preparation phase (i.e. 1-2 months out from competition) we often like to plan race-simulation rides, which, in addition to providing a good opportunity gain familiarity with riding at a race-like intensity, practice technical skills and so on, also allows a great chance to test and finesse your race nutrition.

If you take just one thing from this chapter of the guide, it’s to practice, practice, practice when it comes to race nutrition!

Carbohydrate-Loading (Or Unloading!)

The average endurance cyclist stores roughly 1500-2500 kcal of glycogen in their muscles and liver. That's enough to fuel around 90-120 minutes of all-out exercise. At the same time, the small intestine can only absorb carbohydrates at a maximum rate of 120g per hour (and many people can only tolerate amounts much less than this). Thus, in order to sustain at least a moderate wattage, where carbohydrates are being burnt at a high rate for many hours, the concept of carbohydrate-loading was developed.

The goal of carbohydrate-loading or 'carb-loading' is to increase the amount of glycogen stored in the liver and muscles above the 'normal' baseline level. This allows a higher wattage to be maintained over a fixed duration, or for time to exhaustion at a given wattage to be extended. Indeed, carbohydrate loading has been shown to extend time to exhaustion at a fixed workload by as much as 20%, and to increase power output during a time trial by around 2-3% (Hawley et al., 1997).

However, carbohydrate-loading only benefits events that last longer than roughly 90-minutes (i.e. those where the muscles' usual glycogen stores would become substantially depleted). Events lasting less than 90-minutes don't challenge these glycogen stores, so there is no benefit in following a carbohydrate-loading protocol.

In fact, carbohydrate-loading can, in some cases, be detrimental to performance. That's because each gram of stored glycogen is bound with 3-4 grams of water. A typical 70kg endurance athlete with high levels of stored muscle glycogen can retain 3-4kg of water due to stored glycogen. Thus, for shorter events where body weight is determinative, carb-loading may not be advisable.

Indeed, a recent study (Schytz et al., 2023) showed that a 'carbohydrate unloading' protocol designed to reduce muscle glycogen levels below the 'normal' level can result in a 2% body weight reduction. In this study, they assessed power output over a 15-minute time trial and a 1-minute maximal effort, and there was no reduction in power output despite the lower glycogen levels. Thus, for certain events, such as short time trials and hill climbs, it might actually be advantageous to 'unload' glycogen stores before a key race.

For events lasting between roughly 30-minutes and 90-minutes, an intermediate carbohydrate 'top-up' approach is advised, where carbohydrates are consumed on the morning of an event to help make sure glycogen levels are 'normalised', but are not necessarily elevated nor lowered relative to typical levels.

We cover protocols for carbohydrate loading, unloading and 'topping up' within our supplementary 'cheat sheets'. We also have an example carbohydrate-loading meal plan within the supplementary materials.

Fibre Intake

Dietary fibre is very important for health, and an essential component of a balanced diet. It contributes to bowel and digestive health, is linked with health-promoting gut bacteria, and helps keep you feeling full, which is important if you're trying to lose body fat.

However, fibre also adds bulk to stools, slows transit times and draws water into the intestinal tract, and thus contributes to increased body weight, without providing any acute performance benefit. There's therefore an argument that it may be beneficial to restrict fibre intake over the ~48-hours before an A-priority race. This can help reduce the total weight of intestinal contents.

While we are not aware of any studies looking at the use of fibre restriction ahead of a cycling competition, there is research from other weight-dependent sports (e.g. combat sports) that aiming for 10g of fibre/day or less over the 48-hours ahead of competition helps to clear out the bowel (Reale et al., 2017). This may result in meaningful weight loss, but it's unclear how much weight can realistically be lost through this strategy. Some people may benefit from restricting fibre intake for slightly longer than 48-hours, depending on the average transit time of their digestive system, which can vary from 10-hours to 96-hours.

Given the important health benefits of fibre, this is not a strategy we'd encourage using too often, but it could be beneficial for a handful of key competitions throughout the year.

Pre-Race Meal

There are a number of things to consider when it comes to the pre-race meal. We'll outline these in turn below.

Gastrointestinal Risk Reduction

First and foremost is ensuring that the foods you consume won't cause any gastrointestinal issues during your event. For this, it's often advisable to avoid foods that are high in fats and fibre, as these can sit in your digestive tract for a long time, and in some cases can trigger or exacerbate digestive issues.

It's also important to be aware of any food sensitivities or intolerances you have. Many people have low-level sensitivities to lactose (found in dairy products), gluten (found in grains like wheat, rye and barley), and/or so-called 'FODMAPS' (which is short for 'Fermentable Oligosaccharides, Disaccharides, Monosaccharides and Polyols'). FODMAPS are a type of carbohydrate that the small intestine absorbs poorly. High-FODMAP foods include honey, apples, ripe bananas, raisins and sultanas, garlic, onions, leeks, beans and cauliflower, to name but a few! Importantly, fructose, which is found in many sports nutrition products, is a high-FODMAP food, and some people do not get on well with these products.

If you know you are prone to digestive issues when racing, it’s worth keeping a food diary noting when you experience symptoms and the foods you’ve eaten, to see whether you can identify any common causes. You can also consult with a dietician or nutritionist who may be able to help you identify the cause.

Top up Glycogen

Another goal of the pre-race meal is often to top-up glycogen stores, which are slightly depleted overnight. For this reason, a pre-race meal is usually predominantly geared towards providing carbohydrates. Indeed, numerous studies have shown that a high-carbohydrate meal consumed within the 1-4 hour window before an event enhances both power output and time to exhaustion over many durations and event types.

In the past, a slight concern with eating before an event was that this results in an insulin spike, and then subsequent suppression of fat oxidation and drop in blood glucose levels when exercise starts. It’s now been shown very convincingly that even though there is an insulin spike after consuming a pre-race meal, which has metabolic impacts that can last up to several hours, consuming carbohydrates within 1-4 hours before a race is still overwhelmingly performance-enhancing.

As mentioned above, in certain cases, where events are very short and hilly, then it might be beneficial to allow glycogen levels to be somewhat ‘depleted’ when starting an event, in order to reduce body weight. In these cases, then it’s not necessary to focus on topping up muscle glycogen before an event. We cover these situations in our ‘cheat sheets’.

Avoid 1-Hour Window

The above notwithstanding, the drop in blood glucose is more pronounced when carbohydrates are eaten in close proximity to an event (i.e. within around 60-minutes). Although there’s no conclusive evidence to suggest that eating carbohydrates in this 60-minute window consistently impairs performance, it does seem that some individuals respond badly to eating within this timeframe. It’s therefore good practice to avoid eating in this period if possible.

Many people forget that drinks can also contain calories, and particularly carbohydrates, which can trigger an insulin response, so it’s best to stick to water, or sugar-free drinks within an hour of your event.

10-Min Central-Nervous System Boost

One notable exception to the 60-minute 'no-carb' window is in the 10-minutes before competition. In this short period, it's actually safe and indeed beneficial to consume a small amount of carbohydrates (e.g. a gel or a few sweets). This is because there isn't sufficient time for the sugar to be digested and absorbed from the intestine and trigger an insulin response before exercise begins. Once exercising, the body's insulin response is reduced.

Taking carbohydrates within this 10-minute window is beneficial even for events where glycogen stores aren't a limiting factor (e.g. those shorter than 90-mins). This is because these carbohydrates have a very fast-acting effect on the 'central nervous system', which reduces perception of effort. Indeed, studies have even shown that it's not necessary to ingest carbohydrates to see this benefit, and merely holding carbohydrates in the mouth for 5-10 seconds is sufficient to send a signal to the central nervous system and trigger a performance boost.

Manipulating Glycemic Index

It's been suggested that low glycemic index (GI) carbohydrates may be particularly performance-enhancing before a race, due to the slower and more sustained release. Evidence for a performance-benefit is not conclusive, but it doesn't seem to be detrimental to performance, so this might be something you want to test out in training to see how it feels.

Manipulating Protein Intake

Protein intake should usually be kept low or moderate, because this is slow to digest, and so can sit in the digestive tract for a long time, and potentially contribute to gastrointestinal problems.

However, in ultra-distance events and stage races, there might be a benefit to consuming a slightly higher amount of protein (e.g. 10-20g) in the pre-race meal, as there is some evidence to suggest this might help prevent muscle protein break-down and reduce muscular damage in these types of events.

Example Pre-Race Meals

In the table below, we've included some example pre-race meals. The first three contain a total of 120g of carbohydrates, which should broadly be appropriate for cyclists of a range of weights, although the amounts can be tweaked to suit.

The final meal (for the nervous or time-crunched athlete) includes slightly less carbohydrate (70g). This is because, if you're nervous or short on time before a race, it can be hard to get a large amount of food down. In this scenario, we've suggested sticking to liquid forms of energy, because these can be easier to consume in a limited time, or when appetite is suppressed due to nerves.

Standard	Lower GI	Low-FODMAP, gluten and lactose	Nervous/time-crunched athlete
400g tin of low-fat rice pudding (60g carbs). 250ml orange juice (25g carbs). 2x wedges of honeydew melon (25g carbs). Latte made with 200ml skimmed milk (10g carbs).	1.5x bagel with 150g fat-free cottage cheese (85g carbs). Large banana with 15g peanut butter (25g carbs). Latte made with 200ml whole milk (10g carbs).	Porridge made with 60g oats, 200ml unsweetened rice milk and 20g sugar (80g carbs). 1 cup blueberries (15g carbs). Large banana (25g carbs). Latte made with 200ml almond/hemp milk, and 2x tsp sugar (10g carbs).	250ml strawberry and banana smoothie (25g carbs). 500ml sports energy drink mixed up to contain 45g carbs.
TOTAL CARBS: 120g	**TOTAL CARBS: 120g**	**TOTAL CARBS: 120g**	**TOTAL CARBS: 70g**

Table 5. Example pre-race meals. Carbs = carbohydrates.

Carbohydrate Intake During Race

How Much Carbohydrate?

During a race, there's a clear benefit to taking on carbohydrates as a means to improve performance.

For events lasting less than roughly 75-mins, the main benefit comes from the impact on the central nervous system, as described above. It's therefore not necessary to take on large amounts of carbohydrate, and generally something in the region of 20-30g/hour will be plenty. For those who suffer from gastrointestinal discomfort, you can even avoid consuming any carbohydrates, and instead just suck, chew or rinse a high-carbohydrate sweet/beverage around your mouth for at least 5-10 seconds to see a performance boost. This has been shown to enhance performance at intensities above 70% $\dot{V}O_{2max}$ by as much as 2-3%.

As events increase in duration, then the recommended intake of carbohydrates progressively increases, as carbohydrates need to be provided as a fuel source, in addition to providing a central nervous system benefit. The exception to this rule is for ultra-distance events, which are performed largely at a lower intensity and thus rely more on fat rather than carbohydrate combustion. Given this fact, we usually recommend a slightly lower carbohydrate intake for ultra-distance races, because this allows for more variety in the foods you consume, and helps to avoid so-called ‘flavour fatigue’. You can refer to the ‘cheat sheets’ to see the recommended intakes for different types of events.

You should start taking in carbohydrates early on in a race (e.g. within the first 20-45 minutes), to help avoid glycogen depletion, and smooth out your carbohydrate intake across lots of smaller doses, which can help minimise stomach issues.

Maximum Absorption Rates

One important thing to bear in mind is that there is an upper-limit to the rate at which carbohydrates can be absorbed by the small intestine. If carbohydrates are consumed in excess of this threshold, they will sit in the digestive tract, and can pull water into the small intestine, which can lead to feelings of bloating, discomfort and/or nausea.

The maximum rate at which carbohydrates can be absorbed depends on the mix of carbohydrates you’re consuming (e.g. glucose, fructose, galactose, maltodextrin etc.). That’s because different carbohydrates follow a different digestive pathway, and are taken on by different ‘transporters’ in the small intestine. We can think of transporters like doorways out of the intestine and into the bloodstream, as illustrated in the figure below.

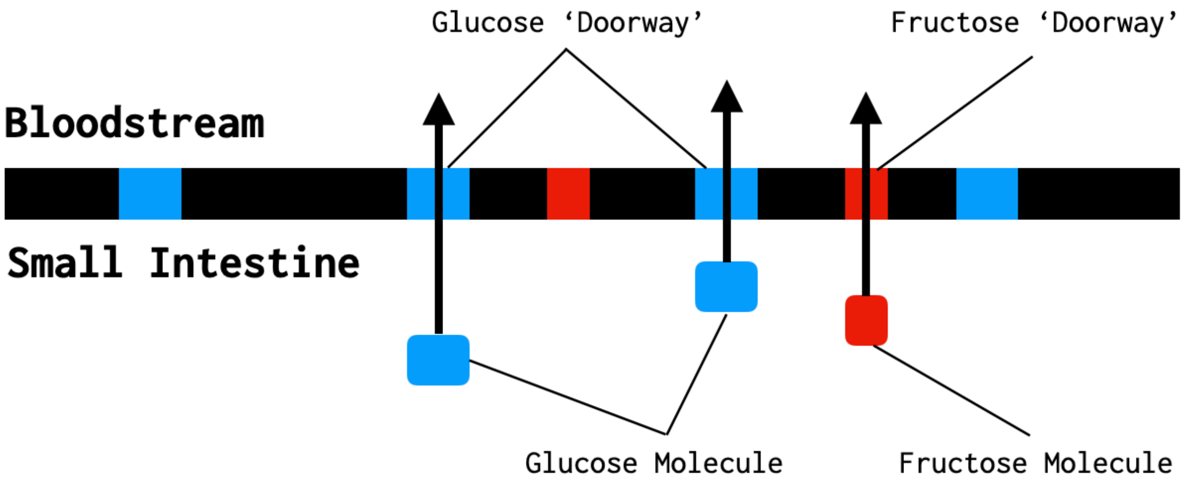

Figure 6. Simplified diagram illustrating the different ‘doorways’ (i.e. transporters) for absorption of glucose and fructose between the small intestine and the bloodstream.

Two key carbohydrates we commonly see in sports nutrition products are glucose and maltodextrin. The former is a simple sugar that can be directly absorbed at the small intestine, without needing to be broken down. Maltodextrin is effectively a long string of glucose molecules, which once broken down, is absorbed in the same way as pure glucose. In effect, therefore, these two types of carbohydrate compete with one another at the intestinal ‘doorways’. The maximum rate at which these carbohydrates can be absorbed is roughly 60g/hour.

Fructose, on the other hand, is another type of sugar that’s often seen in sports nutrition products. Fructose uses different intestinal transporters to pass from the gut to the bloodstream. Previously it was thought that the maximum rate at which fructose can be absorbed is 30g/hour. Accordingly, many sports supplements contain a glucose/fructose or maltodextrin/fructose ratio of 2:1, allowing for a total maximum rate of carbohydrate intake of 90g/hour. These are referred to as ‘multiple-transportable carbohydrates’ (MCTs).

More recently, it’s been shown that a slightly higher rate of absorption can be achieved by combining maltodextrin and fructose in a ratio of 1:0.8. Some newer supplements (such as SIS ‘Beta Fuel’) use this ratio, which allows a maximum intake rate of around 120g/hour.

Maltodextrin is generally preferred over glucose, due to its lower ‘osmolality’ for a given energy content, meaning it allows for more effective absorption of fluids from the small intestine (and may also facilitate faster gastric emptying from the stomach, although this is debated).

As we alluded to in Chapter 5, in practice, even when multiple-transportable carbohydrates are used in the appropriate ratios, in practice, it’s not always possible to take on carbohydrates at rates of 90-120g/hour. This is due to inefficient absorption. However, studies have shown though that it’s possible to ‘train the gut’ to be able to better tolerate carbohydrate intakes in the region of 90-120g/hour, by increasing the density of transporters in the small intestine. We discuss strategies for training the gut in Chapter 5.

Sources of Carbohydrate

Carbohydrates can be taken on in the form of real foods, sports supplements (e.g. gels and bars), or through fluids, and broadly speaking the choice is entirely down to your own preferences.

However, there are a few points worth noting:

- For most events, you’ll want to make sure you’re picking foods that are low in fat, protein and fibre and are fast to digest, which helps to minimise the risk of gastrointestinal issues. Most sports supplements (e.g. bars, gels and energy drinks) meet these criteria, but you can also opt for ‘real foods’ such as sweets, bananas, jam sandwiches with white bread, and homemade energy cakes/balls incorporating rice, oats, dried fruit etc.

- If you’re looking to take on carbohydrates at a rate that exceeds roughly 60g/hour, then it’s best to use sports supplements that include multiple-transportable carbohydrates in the appropriate ratios. Otherwise, you run the risk of getting stomach issues. Energy gels or chews are often the best ways to take these in, as it's much easier to keep track of your carbohydrate intake from hour to hour.

- If using energy gels, you will need to make sure you also consume some water and/or low-carbohydrate electrolyte drink alongside this. This is important, as it helps to dilute the concentration of the carbohydrates in the gel, facilitating better digestion and absorption. The amount of fluid to drink will depends on the formulation of the gel, so you should refer to the instructions on the gel packet.

- If using energy drinks, make sure these are isotonic or hypotonic (see Chapter 7), with hypotonic solutions being preferred if you also plan to take on energy via other sources.

- For very long-distance events, such as ultras, the overall intensity is much lower, and foods with a little fibre, fat and protein can be tolerated without any stomach problems. This helps increase the variety of foods that you can eat, which helps to avoid so-called 'flavour fatigue' (i.e. a loss of appetite that can often be experienced in events like this). Another good tip for avoiding flavour fatigue is to make sure you have a mixture of sweet and savoury foods available. Some good savoury options include boiled and salted potatoes, sandwiches, wraps and cold pizza.

- There's some evidence that incorporating a small amount of protein (roughly 0.25g per kg of body weight per hour) alongside carbohydrates can help reduce muscle damage in long events. Some sports supplements such as gels now contain 'branched chain amino acids' (BCAAs) for this purpose[9]. However, as cycling is not an eccentric activity, the degree of muscle damage is quite small relative to other sports such as running. So, the benefits of protein intake during a long cycling event are unclear. Nevertheless, there doesn't seem to be a risk to consuming protein in long events, and therefore this is a strategy that may be worth testing in training and potentially incorporating in your race. We've highlighted events where protein may potentially be beneficial in our cheat sheets.

- Finally, it's worth reiterating that some people find fructose hard to digest. If you tend to struggle with stomach issues when taking sports supplements, it's worth trying some supplements that don't contain fructose, to see whether you tolerate these better.

Example Race Nutrition Plans

We've included some example race-plans for different types of event over the next few pages:

[9] We discuss BCAAs in more detail in Chapter 9.

NUTRITION PLAN FOR 4-HOUR SPORTIVE				
Time	**Food/Fluid**	**Hydration**	**Carbohydrates**	**Caffeine**
0-mins	Gel + Drink	600ml	45g	
20-mins	Gel + Water	200ml	20g	
40-mins	Bar		25g	
60-mins	Caffeine Gel + Drink	600ml	45g	90mg
80-mins	Gel + Water	200ml	20g	
100-mins	Bar		25g	
120-mins	Gel + Drink	600ml	45g	
140-mins	Gel + Water	200ml	20g	
160-mins	Bar		25g	
180-mins	Gel + Drink	600ml	45g	
200-mins	Gel + Water	200ml	20g	
220-mins	Bar		25g	
Totals		**3.2L**	**360g**	**90mg**
Hourly Rate		**800ml/hour**	**90g/hour**	**30mg/hour**

Table 6. Example race nutrition plan for a 4-hour sportive.

The plan above is for a sportive lasting 4-hours, where the aim is to achieve carbohydrate intakes at a rate of 90g/hour.

In the plan above, the energy gels contain 20g of carbohydrates, the drink contains a mixture of electrolytes and carbohydrate, mixed up to a concentration of 4g/100ml of carbohydrate (i.e. a hypotonic concentration), and the bar contains 25g of carbohydrates.

All carbohydrates are a mixture of maltodextrin and fructose in a 2:1 ratio. Caffeine gels contain 90mg of caffeine. The hourly rate of caffeine takes into account the fact that a 90mg dose of caffeine was also taken 1-hour before the start of the event.

Fluid intakes are relatively high in order to help improve digestion and absorption of carbohydrates, but this would also need to be adjusted to suit individual sweat rates, environmental conditions, and so on. The drink is to be sipped slowly across each 1-hour window.

NUTRITION PLAN FOR 8-HOUR AUDAX/RANDONNEUR				
Time	**Food/Fluid**	**Hydration**	**Carbohydrates**	**Caffeine**
0-mins	Sweets + Drink	600ml	40g	
30-mins	Banana		20g	
1-hour	Sweets + Drink	600ml	40g	
1.5-hours	Jam Sandwich		20g	
2-hours	Sweets + Caffeine Drink	600ml	40g	90mg
2.5-hours	Boiled Potatoes		20g	
3-hours	Sweets + Drink	600ml	40g	
3.5-hours	Jam Sandwich		20g	
4-hours	Sweets + Caffeine Drink	600ml	40g	90mg
4.5-hours	Boiled Potatoes		20g	
5-hours	Sweets + Drink	600ml	40g	
5.5-hours	Gel		20g	
6-hours	Sweets + Caffeine Drink	600ml	40g	90mg
6.5-hours	Gel		20g	
7-hours	Sweets + Drink	600ml	40g	
7.5-hours	Gel		20g	
Totals		**4.8L**	**480g**	**90mg**
Hourly Rate		**600ml/hour**	**60g/hour**	**45mg/hour**

Table 7. Example race nutrition plan for an 8-hour Audax/Randonneur.

The plan above is for an Audax/Randonneur lasting 8-hours, where the aim is to achieve carbohydrate intakes at a rate of 60g/hour. Due to the length of the event, we incorporate a mixture of sports drinks and real foods, and integrate some protein within the plan to help lessen muscle damage.

The drink is a sports drink containing electrolytes, BCAAs (Branched Chain Amino Acids) and carbohydrates, mixed up to a concentration of 4g/100ml of carbohydrate (i.e. a hypotonic concentration).

The jam sandwich is made from one slice of white bread and contains 20g carbohydrate in total. The boiled potatoes are in portions weighing 130g, and are salted to provide additional electrolytes and help promote thirst and prevent flavour fatigue.

The sweets are in portions weighing 20g.

Fluid intake rates would need to be adjusted to suit individual sweat rates, environmental conditions, and so on. The drink is to be sipped slowly across each 1-hour window.

NUTRITION PLAN FOR 1.5-HOUR CROSS-COUNTRY RACE			
Time	**Food/Fluid**	**Hydration**	**Carbohydrates**
0-mins	Drink	250ml	15g
30-mins	Drink	250ml	15g
1-hour	Drink	250ml	15g
Totals		**4.8L**	**45g**
Hourly Rate		**500ml/hour**	**30g/hour**

Table 8. Example race nutrition plan for a 1.5-hour cross-country race.

The plan above if for a cross-country MTB race lasting roughly 1.5-hours, where the aim is to achieve carbohydrate intakes at a rate of ~30g/hour. Due to the shorter length of the event, and the technical terrain, all carbohydrates are delivered via isotonic sports drinks, mixed at a carbohydrate concentration of 6g/100ml.

Post-Race Nutrition

For most race formats, post-race nutrition is not overly critical, as you won't be racing again for at least a few days, or more likely weeks!

However, if you're competing in a stage race, or have several races over multiple days, then post-race nutrition becomes more important.

The priorities for post-race nutrition are to:
1. Replenish muscle glycogen levels
2. Promote muscle repair
3. Reduce any inflammation caused by racing
4. Rehydrate and replace electrolytes that have been lost (covered in Chapter 7)

Generally-speaking, muscle glycogen levels can be replenished within 24-hours of normal food intake, provided carbohydrate intake meets general daily recommendations, as described in Chapter 4.

However, if you need to replenish glycogen levels more rapidly, then research suggests a carbohydrate intake of 1-1.2g/kg/hour during the first 4-6 hours after a race/event is optimal. The first meal should be within 30-mins of finishing the race, and then high-carbohydrate meals/snacks should be eaten every 15-30-minutes, focussing on high-GI foods. The timing and frequency of eating, and the high GI of the foods helps to keep 'GLUT-4' transporters close to the muscle fibre surface. These transporters are responsible for shuttling carbohydrates into the muscle, but need to be at the muscle fibre surface for this to happen.

Eating 1-1.2g/kg body weight of carbohydrates shortly after finishing a hard race is quite a challenge, and if it's not possible to consume carbohydrates at this rate, then there are some strategies you can take. In particular, consuming caffeine (roughly 3-5 mg/kg body weight) and/or protein (roughly 0.2–0.4 g/kg body weight per hour) can also boost glycogen repletion. Protein intake also helps to promote muscle repair.

In relation to reducing inflammation, there is some good scientific evidence that tart cherry juice may be beneficial, and has been shown to meaningfully speed up recovery. We discuss tart cherry juice more within Chapter 9 of this guide.

The guidance above may also relate to ultra-distance cyclists who are competing in continuous multi-day events. Unlike stage races, there is often not a clearly defined recovery period in ultra-distance events. Nevertheless, the guidance above would still be useful to consider when stopping for a break, or short sleep. For example, if you plan to stop riding for several hours, it would be advisable to make sure you consume a meal containing at least 1-1.2g/kg body weight of carbohydrates, and around 20g of protein within 30-mins of stopping in order to promote glycogen resynthesis and muscle repair. You can also consume an electrolyte drink to help rehydrate and a dose of tart cherry juice. The tart cherry juice may also help improve sleep quality if stopping for a short nap.

It's worth noting that alcohol can slow down rates of glycogen resynthesis, and rehydration, and so is best avoided when fast recovery is needed.

Extreme Environments

Certain extreme environments can impact energy metabolism. Below we've summarised the key factors to consider.

Cold Environments

Cold environments trigger a shift towards increased reliance on carbohydrates, and reduced ability to use fats for fuel. In these environments, glycogen stores can be depleted more rapidly. There may be a benefit to carbohydrate-loading before shorter events (e.g. ~1.5 hours), and to consuming carbohydrates at a higher rate during an event (up to the maximum intake rate of 90-120g/hour).

Hot Environments

In hot environments, carbohydrate oxidation rates are lower. There is also less blood flow to the intestines (due to increased blood flow to the skin for cooling). This can slow down the rate at which nutrients can be absorbed from the gut. Gastric emptying is also impaired in the heat.

Thus, in hot environments, it may be advisable to take on carbohydrates at a slightly lower rate (e.g. up to 60-70g/hour), to reduce the risk of gastrointestinal issues. We'd also recommend using a higher proportion of sports-specific foods (e.g. bars and chews) rather than 'real food', because sports foods are formulated to maximise digestion and absorption rates.

Finally, in hot environments, it might be advisable to avoid energy drinks, because this allows you to separate energy and hydration, and make sure these are both taken in at appropriate rates. Relying too heavily on energy drinks in hot environments can either lead to excessive carbohydrate intake and associated gastrointestinal problems (if drinking to meet hydration needs) or inadequate fluid intake and associated dehydration (if drinking to meet carbohydrate needs).

Altitude

When acutely exposed to altitude (i.e. before altitude adaptation has taken place, which can take around 20-30 days), the ability to use carbohydrates for fuel is suppressed. Research also suggests that consuming carbohydrates during exercise at altitude may have less of a performance benefit than at sea level. Overall, therefore, the optimal carbohydrate intake during competition is probably lower at altitude than at sea level.

Chapter Summary

- The key principle of race nutrition is that you should test any and all foods, fluids and supplements you plan to use in your race beforehand, ideally during training sessions that replicate the demands of a race, or in lower-priority races.
- Carbohydrate loading is well known among cyclists, but it's important to recognise that it's not always an appropriate strategy, particularly in short, weight-dependant events such as hill climb time trials.
- We strongly recommend avoiding consuming any energy-containing foods and fluids between 10-60-mins before an event, as this can lead to a substantial drop in blood glucose levels upon beginning the race, and can heighten perception of effort.

- Carbohydrates immediately before or during a race not only provide important fuel for events lasting ~75-mins or longer, but also provide a performance boost via the central nervous system in shorter events. In order to obtain this latter benefit, carbohydrates don't necessarily need to be ingested, but merely 'sensed' in the mouth for 5-10 seconds.
- There's a maximum rate at which carbohydrates can be taken on during exercise, and this rate depends on the composition of carbohydrates consumed. If sticking to sports nutrition products with a 1:0.8 ratio of maltodextrin to fructose, the maximum intake rate is around 120g/hour. If using 'real' foods or a mixture of 'real' and sports products, then it's safer to stick to an intake rate of roughly 60g/hour as a maximum.
- If rapid refuelling is needed (e.g. for a stage race), then you should aim to consume 1-1.2g/kg body weight of carbohydrates within 30-mins of finishing your first event, and then continue to eat high-carbohydrate snacks every 15-30 minutes for ~4-hours. Consuming caffeine (roughly 3-5 mg/kg body weight) and/or protein (roughly 0.2–0.4 g/kg body weight per hour) can also boost glycogen repletion if carbohydrate intake is sub-optimal.
- Environment can impact nutritional requirements, and nutritional strategies may need to be adjusted for extreme conditions.

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Chapter 9: Supplements

Cost-Benefit Analysis

There are various supplements that may enhance performance in cycling. However, supplements should only be considered when all other aspects of your nutrition have been taken care of. In effect, supplements represent the tip of a nutritional pyramid. If you don’t have the basics right first, your pyramid (and therefore performance gains) won’t be very high, as illustrated in the figure below!

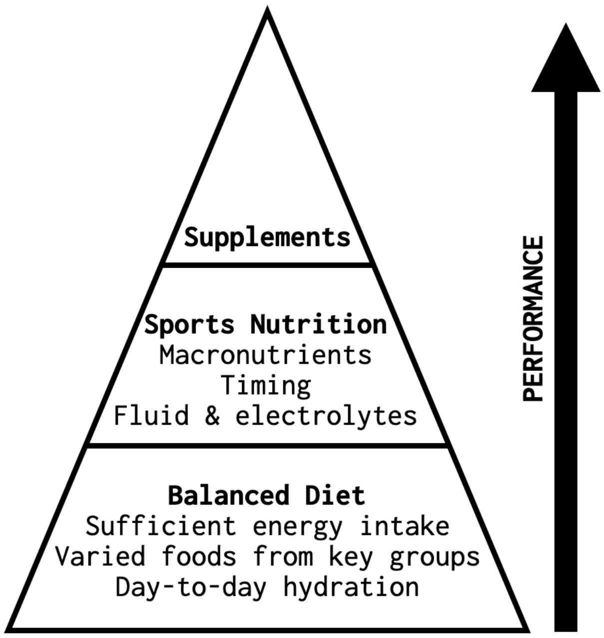

Figure 7. Sports nutrition pyramid, illustrating the relative importance of different nutritional considerations.

In addition, supplementation comes with risks, including side effects that could derail a race, as well as the risk of consuming banned substances. So, it’s always wise to perform a cost-benefit analysis before taking any supplements. In other words, do the expected benefits outweigh any potential risks?

Risk Reduction Strategies

Banned Substances

As mentioned very briefly above, some supplements can include banned and/or dangerous substances. These can either be added intentionally to boost the effects of the supplement or more often, are included accidentally through contamination during the manufacturing process.

Indeed, studies have found contamination rates of dietary supplements to be as high as 20% (Maughan, 2005). Ignorance is not an accepted excuse for doping in cycling, so it's important to take steps to make sure your supplements aren't contaminated. We'd therefore always advise that you only use supplements that are certified by INFORMED, which is an independent body that verifies the quality of manufacturing processes and performs testing to check for banned substances within products.

There are two levels of certification. The highest level is the 'INFORMED Sport' certification. With this level, every batch of supplement is tested for banned substances before being sold. This offers the highest level of confidence that a supplement has passed the most stringent testing and is safer for use. INFORMED Sport also has a mobile app, in which you can scan the barcode of a product to find its testing information, including tested batch/lot numbers.

The other INFORMED certification is 'INFORMED Choice', which provides spot-testing of products. Products are bought from retail outlets and tested monthly to reduce the risk of contamination. INFORMED Choice currently has over 400 certified products globally.

You can check whether a product is certified either to INFORMED Sport or INFORMED Choice standards by looking for the logos on the product (see below), or visiting www.wetestyoutrust.com.

Figure 8. INFORMED sport and INFORMED choice logos, which can be found on supplement packaging, providing a level of confidence that supplements don't contain banned substances.

Always Trial in Training and Low-Priority Races

Another brief point to make before recommending any supplements is that you should always, always trial these supplements in training and/or low-priority races before using them in your priority events, because different supplements can sometimes have performance-limiting side effects (such as stomach upset, or anxiety).

Check with GP

If you are taking any medications or have any underlying health conditions, you should always check with a qualified medical practitioner before taking any supplements.

Caffeine

The top supplement that we'd recommend for any cycling event, irrespective of its length and characteristics is caffeine. This can help improve power output over a variety of effort types and durations via increased drive from the central nervous system and reduced perception of effort.

> RECOMMENDED INTAKE: We'd recommend taking between **1.5-3mg of caffeine per kg of body weight**. Most commonly, athletes will generally take between 100-150mg in total. It's not advisable to exceed 200mg in one dose. This should be taken **~60-minutes prior** to the start of most events (peak caffeine concentrations in the blood stream are reached roughly 60-minutes after consumption, and these levels then stay stable for quite some time afterwards). However, if it's important that caffeine concentrations are maximised for a short event (e.g. hill climb time trial), it might be wise to take the caffeine slightly earlier e.g. 75-mins beforehand, to make sure peak concentration is reached.

During longer events (e.g. 2-hours upwards), it can also be beneficial to 'top up' with caffeine every 1-2 hours. This is often most conveniently achieved by drinking either a caffeinated drink or using a caffeine energy gel. There is less evidence to guide appropriate dosing, but from experience, roughly 50mg per hour or 100mg every 2-hours works well for many. It's not advised to exceed 400mg of caffeine per day, however, so aim to spread your caffeine intake across the race.

Caffeine can be consumed through various sources, including through your regular diet, as well as via sports-specific supplements (which will have a more reliable caffeine content). We've summarised the caffeine content of several common sources in the following table.

Caffeine Source	Typical Caffeine Content
Caffeine Tablets	50mg/tablet
Caffeine Gum	50mg/gum
Caffeine Gel	75-100mg
Caffeine Energy/Electrolyte Drink	75-100mg per serving
Coffee (espresso, latte, cappuccino etc.)	Between 70-100mg per espresso shot (bear in mind that most coffee shop coffees will include multiple shots)
Filter Coffee	Between 100-300mg depending on size and strength
Instant Coffee	Roughly 50mg for a typical mug size and strength
Tea	Roughly 50mg for a typical mug size and strength
250ml Red Bull	80mg
330ml Coke	30mg

Table 9. Caffeine content of common caffeine sources.

The effectiveness of caffeine does not depend on your usual levels of intake, so there is no need to wean yourself off caffeine to see benefits. It should be noted however that caffeine can induce some side effects, such as feelings of anxiety, heart palpitations and stomach disturbances.

Beetroot Juice/Nitrate

Nitrate is a substance that occurs naturally in green leafy veg, and it plays a role in multiple exercise-related physiological functions. Ingestion of nitrate has been shown to have various benefits. It can increase aerobic efficiency; or in other words reduce the oxygen cost of a given power output. It also helps increase the rate at which oxygen supply is ramped up at the start of exercise, which means that fatiguing metabolites build less quickly. Finally, there is some evidence that longer-term nitrate supplementation can help improve Type II muscle fibre contractility and maximal power output. These are adaptations that may be useful across a range of cycling disciplines, including both long and short events.

> RECOMMENDED INTAKE: The recommended dose for nitrate is **5.0-8.5 mmol (~300-500mg) of nitrate taken once per day for 3-6 days** before competition. Most people consume this via specially concentrated ‘BeetIt’ beetroot shots, which contain 400mg of nitrate per shot (thus taking one shot per day). However, it’s possible to also get this level of nitrate through eating leafy vegetables directly.

An alternative approach is to just take a single dose of nitrate (again between 5.0-8.5 mmol or ~300-500mg) around 3-hours before competition in order to improve cycling economy. However, it does seem that the longer-term dosing strategy over 3-6 days has better evidence for performance enhancement, and in particular, the longer dosing strategy might be necessary to see improvements in Type II muscle fibres and maximal power.

It's worth noting that there is considerable individual variability in responsiveness to nitrate supplementation, so there is no guarantee that you'll see a benefit from this supplementation approach. There is also a general trend for nitrate to be less beneficial in more well-trained athletes (though some highly-trained athletes do still see a benefit!).

Nitrate can also be supplemented in the form of nitrate salts such as sodium nitrate and potassium nitrate. However, these supplements are associated with health risks, so it's recommended that nitrate is only obtained through natural food sources (including e.g. concentrated beetroot juice).

When consumed through natural sources, there are no known side effects from consuming nitrate in the concentrations described above, although the colour of urine and stools can be affected, and may appear dark/red/purple.

Beta Alanine

Fatigue during high-intensity events or efforts (i.e. when riding above threshold) is multi-factorial. However, one factor that seems to contribute to fatigue is the accumulation of hydrogen ions within the muscles and blood. The body has a natural buffer within the muscles to help neutralise these hydrogen ions. This is known as 'carnosine'. Carnosine also has other roles in muscle contraction and it's thought that it may help improve contraction efficiency.

Carnosine is produced naturally within the body. However, supplementation with beta alanine (an amino acid that is involved in carnosine production) has been shown to increase muscular stores of carnosine. Supplementation may be particularly effective in people who eat low amounts of meat, which is the primary source of carnosine in the diet. These people may have low baseline carnosine levels.

There is good evidence that beta alanine supplementation can help improve power output in all-out efforts lasting between 1-10 minutes (Stellingwerff, 2020). Time to exhaustion is typically improved by around 2-3% among recreational cyclists, and around 0.5-1% in highly-trained cyclists. In our experience, beta-alanine also helps with improving functional threshold power, and the speed of recovery between high-intensity efforts, such as those seen in road races.

> RECOMMENDED INTAKE: **3-6g beta alanine/day** over **at least 4-6 weeks**. Take this in **several smaller doses of 0.8-1.6g** spread across the day, each **with a meal or snack**. This helps to increase the proportion of beta alanine that is absorbed into the muscles. It's worth noting that for some people, it can take as much as 24 weeks of supplementation to maximise muscle carnosine stores, so there may be

benefit in supplementing for longer than 4-6 weeks. To further increase the proportion of beta alanine that enters the muscles, it's recommended to look for **slow-release** versions of this supplement.

Once elevated, muscle carnosine levels can be maintained via a lower daily dose of ~1-2g/day. Alternatively, if supplementation is stopped, muscle carnosine levels will slowly fall. When carnosine levels are increased by ~50% through supplementation, it takes 14-15 weeks for levels to return back to baseline.

Beta alanine can result in a side effect known as 'paraesthesia', which is a tingling or prickling of the skin that can last up to 1-2 hours after taking the supplement. This is a completely benign symptom, and doesn't pose a risk to health. No other side effects are believed to exist.

Sodium Bicarbonate

As mentioned in relation to beta alanine, the ability to buffer hydrogen ions appears to help stave off fatigue when riding at high powers (>FTP), and improve the capacity to recover from repeated efforts. Like carnosine, plasma bicarbonate also acts as a buffer for hydrogen ions, but this time in the blood, rather than in muscles.

Supplementation with sodium bicarbonate (also known as bicarbonate of soda, or baking soda) can increase the concentration of bicarbonate in the blood from around 25 mmol/L to around 30 mmol/L, and thereby improve hydrogen buffering capacity. This can result in a mean performance enhancement of 1.7% over a 1-min effort (Jones, 2014). There is also some evidence that bicarbonate is helpful in enhancing the effectiveness of high-intensity training; particularly those involving very high-intensity bouts above ~120% FTP.

RECOMMENDED INTAKE: The classic supplementation regime is to take **~0.3 g per kg** body mass of sodium bicarbonate 1-2 hours before competition. However, this can result in gastrointestinal problems, and it might be better to either:

A. **spread consumption over the 150-120-minutes before the race, taking this alongside a small carbohydrate-based snack and some fluid**.
B. Alternatively, you can pre-load with sodium bicarbonate over **3-5 days, taking between 0.1-0.3 g/kg body weight per day over this period, split across 2-3 meals**. In this scenario, plasma bicarbonate levels seem to stay elevated for around 24-hours, so there is no need for supplementation on the day of the race.

This is definitely a supplement you'll want to practice several times in training and then low-priority racing before implementing it in your priority races, as it can cause gastrointestinal problems. It can also lead to some fluid retention, and thus weight gain due to the increased sodium intake, so we'd would recommend taking care to reduce intake of other sources of sodium (i.e. salt) over the 48-hours before a race, if you're competing in a particularly hilly event.

It's perfectly fine to simply use basic bicarbonate of soda or baking soda bought from your local grocery store. This will certainly be one of the cheapest ways to take this supplement. However, Maurten have recently developed a new bicarbonate supplement (the 'Bircarb System'), which is a combination of a hydrogel and slow-release sodium bicarbonate that helps reduce the risk of stomach issues, and allows the supplement to be taken before a race more safely. This seems to be a more tolerable, but much more expensive option.

Creatine

Creatine is a popular sports supplement, with a strong evidential backing. Its main role is to boost muscle stores of 'phosphocreatine', which is a key source of energy in efforts lasting several seconds. Creatine supplementation can improve strength and power in the gym, and has been shown to enhance the effectiveness of a weight training program. It can also be useful in boosting power output when sprinting. Creatine is found naturally in meat and fish, and therefore vegans and vegetarians may particularly benefit from creatine supplementation.

The key downside of creatine though is that it's associated with notable weight gain (typically in the region of 0.6-1kg). It's therefore not recommended in most cycling competitions, except for track cycling, where body weight is less critical, and max sprint power is very important.

If you'd like to use creatine either for track cycling, or to enhance weight/strength training during a period where you're not racing, then the recommendations are as follows:

> RECOMMENDED INTAKE: Take creatine monohydrate at a rate of 0.3 grams per kilogram of bodyweight per day for 5–7 days. This is the initial loading phase. From here, creatine levels can be maintained by consuming at least 0.03 g/kg body weight per day. It's recommended to take creatine alongside a meal and a drink, and to spread doses out across the day to help reduce side-effects.

Creatine monohydrate is the most common form of creatine, but it can also be found in many other formats. For these, we recommend following the supplementation instructions provided by the supplement manufacturer.

Potential risks with creatine supplementation, are nausea and diarrhoea if consumed in too great a dose in one go, and stomach cramping if insufficient water is consumed at the same time.

Tart Cherry Juice

Tart cherry juice is a relatively new supplement of interest, with increasing evidential support. It contains many antioxidant and anti-inflammatory components, which have been shown to help speed up recovery after strenuous exercise. This includes a reduction in muscle soreness and markers of inflammation and oxidative stress, as well as faster return to peak form. Tart cherry juice has also been linked with improved sleep. This supplement is therefore particularly interesting for multi-day events, including stage races and ultra-distance races.

> RECOMMENDED INTAKE: Consume 250-350ml of tart cherry juice (or 30ml concentrate) 2x per day to aid recovery. It’s recommended you start supplementing roughly 4-6 days before your event, and up to 2 days afterwards for the best effects. Consuming tart cherry juice ~30-mins before sleep can also aid sleep quality.

No specific side-effects from taking tart cherry juice have been reported. However, it’s worth noting that regular use tart cherry juice (as well as other antioxidant supplements like vitamin C or E and green tea) can actually impair adaptations from training. This is because, the oxidative stress caused by exercise is a key signal telling the body it needs to adapt. Suppressing this through antioxidant use effectively dulls this important signal. Therefore, tart cherry juice (and other anti-oxidants) should only be taken when fast recovery is very important (such as between stages of a race), and not to promote recovery from regular training. The same is true of other recovery methods like ice baths. These should only be used where recovery (and not training adaptations) is a priority.

Branched Chain Amino Acids (BCAAs)

You may have come across the term ‘branched chain amino acids’ or BCAA when looking at sports nutrition products. This is a special type of amino acid, with a branched shape, and which comprises the amino acids leucine, isoleucine and valine.

Numerous sports supplements contain one or more BCAAs, where their intended purpose is usually being to help stimulate muscle protein synthesis (i.e. muscle growth) or to help delay fatigue and enhance recovery in endurance training or competition.

BCAAs and particularly leucine have received considerable attention due to their role in triggering muscle protein synthesis, as well as nerve function, glucose/insulin regulation and reduction in subjective feelings of fatigue. Leucine is one of the most potent stimulators of muscle protein synthesis, and many sports nutrition products contain this amino acid in particular. However, more recent research suggests that rather than taking BCAAs/leucine in isolation, muscle protein synthesis is best stimulated through consuming complete proteins containing the full spectrum of essential amino acids.

One of the most effective forms of complete protein for stimulating muscle protein synthesis is whey protein, which is found in dairy products. This appears to be particularly potent because it has a high concentration of leucine, and is digested quickly, allowing a strong ‘hit’ of leucine to be delivered to the muscles.

We wanted to mention BCAAs, given their popularity in the sports nutrition field. However, in the context of cycling, their benefits are less notable. That’s because by far the biggest benefit of BCAAs is in promoting muscle size. In cycling, we generally don’t want to increase muscle size, and instead seek to build muscular strength and power. However, there’s less concrete support that BCAAs promote strength or power adaptations, particularly in endurance cyclists who are concurrently doing endurance training.

The main benefit of BCAAs in cycling appears to be in reducing fatigue and promoting recovery, when consumed alongside carbohydrates during a race. There is therefore a use case for BCAAs in ultra-endurance events or stage races. However, it’s not clear whether BCAAs confer any additional benefit in this context beyond simply consuming high-quality complete proteins. Probably the key benefit of BCAAs is that they can be consumed quite efficiently within a BCAA-enriched energy gel or drink.

Chapter Summary

- We only recommend using supplements that are certified by Informed, which provides a level of confidence that supplements don’t contain banned substances. You should also always check with your GP before taking supplements, particularly if you’re on existing medications or have any medical conditions.
- Any supplements you plan to use should be rigorously tested in training to ensure they don’t cause any detrimental side effects (e.g. gastrointestinal issues).
- Caffeine is a supplement that’s recommended for all cycling disciplines, and has good scientific support. However, some people experience side effects such as gastrointestinal issues, heart palpitations and anxiety.
- Beetroot juice may be beneficial in both long and short cycling events. However, not everyone will see a performance improvement from taking this supplement, and it seems to be less effective in more highly-trained cyclists, in general.
- Beta Alanine helps to buffer hydrogen ions that are produced through anaerobic glycolysis. It’s useful in improving the capacity to ride above threshold, and in aiding recovery from repeated hard efforts. It also seems to help lift FTP. It’s therefore recommended for stochastic disciplines like road races, or cyclocross, and also shorter time trials performed above threshold power.
- Sodium bicarbonate has very similar use cases to beta alanine and works in a similar way to buffer hydrogen ions. However, it can be hard to take this supplement before a race, due to the high rates of gastrointestinal issues, and this is definitely a supplement that needs to be well tested before racing.

- Creatine may be beneficial in certain punchy cycling disciplines requiring strong sprint abilities. However, it contributes to weight gain, and so doesn't have very wide applicability in cycling.
- Tart cherry juice may help speed up recovery and enhance sleep. However, this supplement may also dull training adaptations, so should only be used when fast recovery is a priority.
- Branched chain amino acids are popular in sports nutrition products. However, the evidence of a performance benefit among cyclists is limited.

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Chapter 10: Female-Specific Nutrition

Introduction

Women are metabolically different from men. For example, on average, women oxidise more fat and less carbohydrate for a given relative exercise intensity. This is further complicated by the changing hormone profile of females, both week-to-week (in line with the menstrual cycle) and over the life course (e.g. moving into the menopause), as well as use of hormonal medication such as contraceptives. Female hormones impact a multitude of things including metabolism, fluid retention, sweat rates, and temperature regulation, and have a bearing on sports nutrition recommendations.

As it’s very hard to control for the hormonal fluctuations of women in scientific studies, the vast majority of research into training and performance-related nutrition (and indeed sports science research more generally) has been conducted among men. Accordingly, most sports nutrition recommendations are aligned to a male, and not female physiology.

In this chapter, we’ll do our best at outlining how women’s nutrition may differ from the ‘standard’ recommendations derived from men. There is very minimal scientific evidence in this area, and so many of the recommendations are based on theory, and underlying female physiology.

General Sex Differences

Carbohydrates vs Fat

We’ll begin by first discussing general differences between males and females. As mentioned above, females have a higher propensity to oxidise fat, and a lower propensity for carbohydrate oxidation during exercise. From a nutritional standpoint, this may suggest that women’s daily carbohydrate requirements are a little lower than for men.

The general recommendation for endurance cyclists is to consume between 5-12g/kg per day of carbohydrates, depending on daily energy demands (lower on recovery days). However, females can probably err on the lower end of this range, even on heavier training days.

This also makes sense when we consider that females typically have a lower body weight and lower daily energy demands. If a 55kg female has a basic energy requirement of 1800 kcal, and then has a moderate day of training burning an additional 700 kcal, then their daily energy demand is 2500 kcal. If they were to consume carbohydrates at the higher end of the range (e.g. 9g/kg), then 80% of their daily calories would come from carbohydrates, which clearly doesn't allow enough room for adequate protein and fat intake.

To allow adequate fat and protein intake (~20-30% energy intake and ~1.2-1.6g/kg respectively), the maximum carbohydrate intake for this athlete to maintain energy balance will be roughly 7g/kg. On easier training days, this might be as low as 4-5g/kg.

In contrast to having lower daily carbohydrate needs, females likely have higher carbohydrate needs immediately before and during high-intensity exercise, due to their reduced propensity for carbohydrate oxidation. Thus, females should take particular care to follow fuelling best practices before and during key sessions (e.g. aiming to eat 1-2g/kg body weight of carbohydrates 1-4 hours before a session, and fuelling with carbohydrates during higher-intensity sessions too).

Fluid Requirements

Sweat rates are generally lower in females than males, even when accounting for body weight. This puts females at increased risk of over-drinking during exercise, and developing hyponatremia (which as discussed in Chapter 7, is a dangerous condition where the concentration of sodium in the blood falls below 135mmol/L).

For females, it may be advisable to adopt a more conservative hydration strategy during exercise, aiming to drink to thirst, and being particularly mindful not to over-drink in longer, low-intensity activities.

It's also wise to include electrolytes within any drinks consumed, which can help reduce the risk of developing hyponatremia by replacing salts lost in sweat.

Iron

Menstruating females are at high risk of having an iron deficiency, which as mentioned in Chapter 1, can significantly impact capacity to train, adapt and race.

The prevalence of iron deficiency among female athletes has been estimated to be anywhere between 15% to upwards of 50%.

Females therefore need to take extra care that their iron intake is sufficient, and may need to take an iron supplement if blood loss is high and/or if the intake of 'heme iron'[10] is low.

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[10] Heme iron is from meat and fish sources, and is better absorbed by the body than non-heme iron from other sources e.g. vegetables and legumes.

Impact of the Menstrual Cycle

Understanding the Menstrual Cycle

The menstrual cycle starts on the first day of your period, and finishes on the day before your next period. In females who have a regular cycle, and who are not taking hormonal contraceptives, the menstrual cycle can last between 21 and 40 days, but is typically around 28 days. The cycle can be broadly divided into three key phases: follicular, ovulation and luteal, as illustrated in the diagram below, which is taken from McNulty et al. (2020).

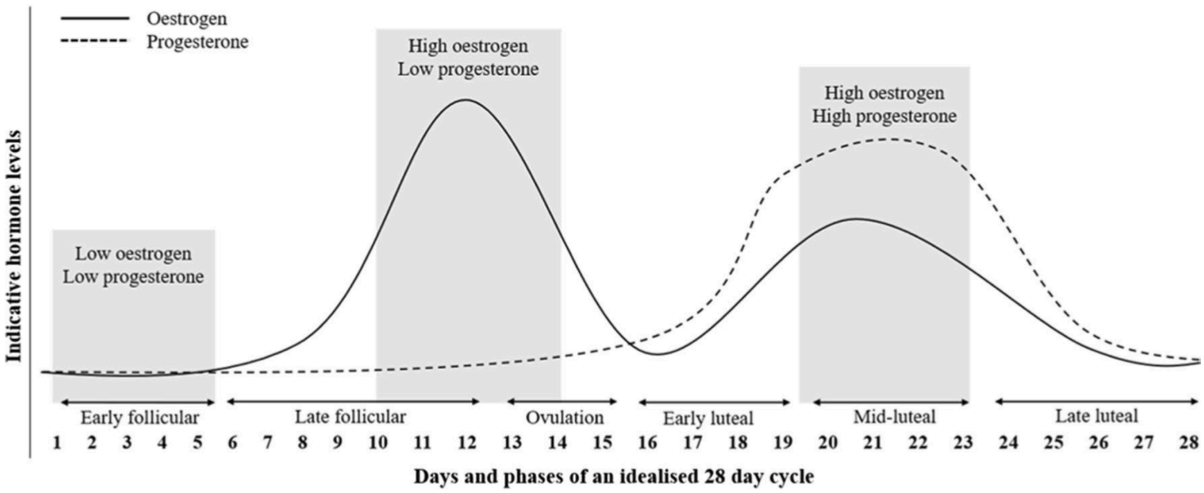

Figure 9. Phases of the menstrual cycle, and associated fluctuations in oestrogen and progesterone levels.

The different menstrual phases are predominantly defined by the profiles of the two key female sex hormones oestrogen and progesterone, as shown in the graph above.

The three main phases can also be divided into sub-phases, based on the levels of female hormones, and can be summarised as:

- **Early follicular**: all hormones are at relatively low levels.
- **Late follicular**: oestrogen is rising, progesterone is low.
- **Ovulation**: oestrogen is falling, progesterone is low.
- **Early luteal**: progesterone and oestrogen are rising.
- **Mid-luteal**: progesterone and oestrogen are high.
- **Late-luteal**: progesterone and oestrogen are falling.

In each of these phases, you can have quite different menstrual symptoms, and abilities to train, perform and adapt, due to the different hormonal profiles.

Impact of Female Hormones on Training and Performance

The two main hormones that interact with training capacity and performance are oestrogen and progestogen.

Oestrogen can be broadly seen as supportive of training and performance. It’s associated with a wide range of physiological changes, including improved vasodilation (i.e. blood flow), increased muscle glycogen storage, reduced muscle catabolism (i.e. less muscle break-down), improved neuroexcitability (i.e. ability to activate muscle fibres), increased fat-burning and glycogen-sparing.

In contrast, progesterone is somewhat negative for training and performance. It promotes catabolism (muscle break-down), impairs fat oxidation ability, and increases body temperature, which has down-stream effects on things like the onset of sweating, skin blood flow, and haemoglobin disassociation, as well as sleep quality and general recovery.

Both hormones also seem to impact fluid retention and sodium handling, as well as neural control of breathing and carbon dioxide handling.

What this means in practical terms

Early Follicular Phase

If you suffer from heavy bleeding, this phase might cause practical obstacles that make training hard (e.g. in terms of your ability or confidence in completing longer training sessions). You might also experience common symptoms of premenstrual syndrome (PMS) such as cramping, back pain, headaches, nausea or diarrhoea, due to high levels of prostaglandins (chemicals released by the uterus during the luteal and early follicular phases), which can impact your mental or physical ability to train.

If your symptoms are particularly severe, then you might need to look to medication. Ibuprofen can reduce prostaglandin levels and lighten menstrual bleeding by around 25% in women with heavy periods, but there are side effects, such as risk of kidney disease and stomach ulcers from long-term use. Alternative medical solutions include tranexamic acid, or Naproxen, which might be even more effective at reducing bleeding. You should consult with a GP before considering these meditations.

In contrast, women who have very minimal PMS symptoms during menstruation may feel relatively strong and able to train and compete well during the early follicular phase. As the levels of female hormones are low during this phase, then this can, in principle, be a time of the month where you can tolerate high training loads, and a mixture of different session types (i.e. both high and low intensities and strength training).

If bleeding is heavy, you should also consider taking an iron supplement during your period to help reduce the risk of developing anaemia and to help the body more effectively replace the red blood cells that have been lost.

Late Follicular Phase

In this phase, oestrogen levels are gradually increasing, which leads to improved fat oxidation, and glycogen storage and improved muscle building abilities. Overall, you will generally be feeling strong, and should recover quite quickly between training sessions, so this is a good time to incorporate higher training loads.

Be aware that oestrogen does reduce your ability to utilise internal stores of carbohydrates, in the form of glycogen. So, you might need to pay greater attention to fuelling with carbohydrates during any intensive training sessions (e.g. at or above your threshold power/FTP). You'll usually want to aim for 1-2g/kg of body weight of carbohydrates between 1-4 hours before an intensive session and between 30-60g per hour of carbohydrates during the session. Provided you attend to this, then overall, this is a very good phase for most types of training.

Ovulation & Early Luteal Phase

Through these two phases, you should have a fairly average capacity to train and perform, because the levels of female hormones are lower, and you will not normally be experiencing any symptoms of PMS (although in some women these can begin in the early luteal phase). Through these phases your hormonal profile is more similar to that of a male, and you can follow 'standard' nutrition guidance through these phases.

Mid Luteal Phase

In the mid-luteal phase, both oestrogen and progestogen are high, and this can have a notable negative impact on training and performance. In particular:

- You may notice you have a higher heart rate, breathing rate, and perceived effort level for a given power output in this phase.
- There is some evidence your lactate threshold/FTP may be slightly lowered.
- You will likely have difficulty utilising stored muscle and liver glycogen, which can make longer and/or high-intensity sessions feel harder.
- High progesterone levels can increase muscle catabolism (i.e. break-down), which can make recovery take longer and make muscle-building harder.
- Core body temperature is increased, which can lead to sleep disturbances, and impaired recovery, and can also increase the risk of overheating during exercise.
- Thirst, sodium regulation, and fluid retention are all altered during this phase, which can increase the risk of developing hyponatremia during prolonged exercise.

In order to address these negative effects, we recommend:

- If possible, aim to align your recovery weeks with the mid-luteal phase of your cycle, so that the volume and amount of intensive training you're aiming to achieve is less demanding.
- If you do need to perform at a high level through this phase (e.g. you have an important competition), then focus on fuelling well with carbohydrates before and during the event, so that blood glucose levels remain high. This may help to counteract the suppressed ability to use stored muscle glycogen. For important competitions aim for 2-4g of carbohydrates per kg of body weight 2-4-hours before your competition and then 60-90g/hour of carbohydrates during.
- For other training sessions, supplementing with some carbohydrates (e.g. 30-60g/hour) may also be advisable. This may help reduce the perceived effort level, and it's been suggested that this may help counteract the catabolic effects of progesterone.
- Increase your protein intake above 1.6g/kg body weight per day, which may also help reduce muscle break-down.
- Counter-intuitively, this may be a good phase to compete in lower-intensity endurance events (e.g. long sportive or ultra-distance events) due to the improved ability to use fats for fuel.
- Take extra care to avoid over-drinking during prolonged exercise, and replace sodium losses with appropriate electrolyte drinks.
- Avoid training with reduced carbohydrate levels through this phase (see Chapter 5), given the potential risk of muscle break-down, and suppressed ability to use existing carbohydrate stores.

Late Luteal Phase

In principle, through this phase, as levels of oestrogen and progesterone fall, there should be an improvement in performance and training capacity. However, changing hormone levels can trigger PMS symptoms in many women, and these can negate any benefits from lowered hormone levels. In particular, mood-related symptoms usually peak in the late luteal phase.

For women who experience few PMS symptoms, or who are able to manage these through other methods (as described above) then this can be a phase where you should be able to tolerate more normal training loads, and follow more 'standard' sports nutrition recommendations.

The key points are summarised in the following table.

	Early Follicular	Late Follicular	Ovulation	Early Luteal	Mid Luteal	Late Luteal
Cycle Days	~1-7	~7-13	~14	15-19	19-23	23-28
General Symptoms	High risk of PMS symptoms (cramps, back-ache, headaches, mood disturbances, diarrhea).				High risk of PMS symptoms (cramps, back-ache, headaches, mood disturbances, diarrhea).	High risk of PMS symptoms (cramps, back-ache, headaches, mood disturbances, diarrhea).
Training and Performance Specific Symptoms	If PSM symptoms can be alleviated, you should have a 'normal' capacity to train, adapt, recover and perform.	Heightened ability to train, recover and build muscle. Will generally be feeling 'strong'. Reduced ability to access stored glycogen may make higher-intensity sessions slightly harder.	'Normal' capacity to train, adapt, recover and perform.	'Normal' capacity to train, adapt, recover and perform.	Reduced ability to train, recover and build muscle. May notice increase in perceived effort. Reduced ability to access stored glycogen may make higher-intensity sessions slightly harder.	If PSM symptoms can be alleviated, you should have a 'normal' capacity to train, adapt, recover and perform.
Nutritional Recommendations	Ibuprofen can help reduce blood loss and alleviate pain. If symptoms are very severe, may benefit from medical intervention - consult GP. Take an iron supplement to reduce risk of iron deficiency from blood loss.	Can plan a higher load of training than normal this week. Focus on fueling well with carbohydrates before and during intensive training sessions. Endurance and strength sessions are particularly well-suited to this phase due to anabolic effects of oestrogen and improved fat oxidation ability.	Follow standard nutrition recommendations through this period.	Follow standard nutrition recommendations through this period.	This may be a good time to plan a recovery week. Focus on fueling well with carbohydrates before and during training/competition and increasing protein intake beyond 1.6g/kg body weight per day to improve performance and minimise muscle break-down. Take sports supplements containing electrolytes and avoid over-drinking during longer sessions/races, particularly if it's warm. Consult GP around strategies to reduce PMS symptoms if these impact ability to train.	Consult GP around strategies to reduce PMS symptoms if these impact ability to train.

Table 10. Summary of menstrual phases, and associated guidance.

Hormonal Contraceptives

There are a wide range of hormonal contraceptives available, which can have a variety of physiological effects depending on which ones are used.

The majority of research that does exist has been conducted on the combined oral contraceptive (commonly termed ‘the pill’). Some of the strongest evidence we have at the moment comes from a meta-analysis that pooled data from a number of studies on oral contraceptive use and markers of aerobic and anaerobic performance. Importantly, this study found that, on average, performance was impaired by oral contraceptive use (Elliott-Sale et al., 2020).

It’s thought that this performance-impairment might be because hormonal contraceptives down-regulate the production of endogenous oestrogen and progesterone. So, through the whole cycle, the hormonal profile appears similar to the early follicular phase. This is true even if a pill-free week is taken, as there is insufficient time for endogenous hormone production to increase.

Another big disadvantage of using hormonal contraceptives is that they mask your regular cycle, which as discussed in Chapter 6, is a very useful barometer of health and sufficient energy intake.

For some women though, hormonal contraceptives can help to alleviate symptoms that interfere with training and performance (such as heavy periods, cramps, and low mood). Some also like that it helps with altering the timing at which bleeding occurs, so that it does not coincide with important races, or training camps, for example. Thus, for some women, the benefits of taking the oral contraceptive outweigh the potential negatives.

From a nutritional standpoint, it’s hard to make any firm recommendations around use of the pill and performance nutrition, because there simply isn’t enough evidence.
Some combined oral contraceptives have been found to negatively impact glucose uptake, suggesting women on oral contraceptives might have heightened carbohydrate needs, particularly during high-intensity training or racing. The combined pill can also lead to increased body temperature, impacting a range of things such as the onset of sweating and skin blood flow. Studies also indicate that some oral contraceptives increase fluid retention, leading to weight gain and a potentially increased risk of hyponatremia in long events. Thus, care may need to be taken when hydrating during exercise to avoid over drinking, and ensuring electrolytes are included in fluids.

We also currently have very little scientific data on other forms of hormonal contraception (e.g. the hormonal coil, the progestogen only pill, and the implant).
It’s been suggested that forms of contraception such as the hormonal coil, that deliver a very low and targeted dose of progestin directly to the uterus might be the best type of hormonal contraceptive for women wanting to minimise potential negative impacts on performance. This is because this avoids systemic hormone circulation and doesn’t suppress endogenous oestrogen production. To our knowledge, there is no scientific evidence to support or refute this theory at present, but the logic behind it does make

sense! Whatever you decide, you should always consult with a GP before taking any forms of hormonal contraception, and bear in mind that there can be wider health implications and side effects.

Menopause

Women entering their 40s may start to see changes in the levels of sex hormones, as they enter the perimenopause. During this phase, oestrogen levels fluctuate and then fall over a period of 5-10 years, and the menstrual cycle becomes more irregular. Menopause is then defined as the point at which periods cease entirely, at which point the ovaries no longer produce oestrogen or progesterone.

A detailed discussion of menopause and perimenopausal symptoms is beyond the scope of this guide. However, from a nutritional standpoint, there are a few things to be aware of.

Temperature Regulation

Temperature regulation is thought to be harder during the (peri)menopause. Caffeine and alcohol can exacerbate this, and trigger 'hot flushes', so are best avoided.

There is some evidence to suggest that after menopause, women sweat less, yet have higher core body temperatures. To combat this, you can opt for cold drinks before and during exercise wherever possible. This may also be a useful strategy to reduce body temperature before bed to improve sleep (see below).

Sleep

Sleep is disturbed during the (peri)menopause, which can impact both your energy to train and compete, as well as slow down recovery. There is some evidence to suggest that drinking a glass of tart cherry juice before bed can help promote sleep (see Chapter 9 for more on this). Taking ~400mg of valarian root, either as a tea or capsule is another option to aid sleep, although the evidence is less convincing.

Carbohydrate Tolerance

There is some evidence to suggest that after menopause, women become more resistant to insulin, which means carbohydrates aren't as well tolerated. Some sources also suggest the ability to metabolise fructose is reduced. This might suggest that menopausal women should aim for slightly lower carbohydrate intakes both across the day, and during exercise. It's been suggested, for example, that an upper limit of 40-50 grams per hour is advisable, rather than the standard 60-90g/hour upper-limit. Again, there is little evidence to make conclusive recommendations, so this is something to experiment with in training to see what works best for you as an individual.

Muscle Protein Breakdown

As you age, it becomes harder to build muscle, and muscle break-down increases in a condition known as ‘sarcopenia’ (the gradual loss of muscle mass). This is thought to be exacerbated by the drop in oestrogen levels.

Menopausal women therefore require higher intakes of protein than the general population in order to stimulate muscle protein synthesis (i.e. muscle growth). However, as discussed above, it’s unclear whether menopausal women (and older cyclists more generally) need protein intakes that exceed the already heightened recommendations for athletes.

To be on the safe side, we recommend aiming for daily intakes of at least 1.6g/kg body weight per day, focussing on high-quality proteins, and aiming to have around 4-5 protein feedings spread throughout the day.

Bone Health

Women start losing bone at an earlier age and at a faster rate than men, due to the drop in oestrogen, which makes it harder for the body to retain calcium from dietary sources. Accordingly, calcium requirements for menopausal women are slightly higher than for younger women (some sources suggest as much as 1200mg/day is needed).

As vitamin D is critical to calcium absorption, it’s also important to ensure adequate intake of this nutrient either via sun exposure or supplementation.

Chapter Summary

- Females have a higher propensity to oxidise fat than males, and have lower sweat rates, even when accounting for differences in body weight.
- Menstruating women may find that during the mid luteal phase (~1 week before the period starts) and the early follicular phase (during bleeding), performance can be compromised, with the former being largely due to high levels of oestrogen and progestogen, and the latter being a result of heavy bleeding and prostaglandin levels which can cause cramps, headaches etc.
- During the mid luteal phase, it’s harder to access muscle glycogen and there’s an increased tendency to break down muscle for fuel. This, particular attention to carbohydrate and protein intake is needed through this phase to support training, adaptations and performance. Care should also be taken with replacing fluids and electrolytes, as thirst and sodium regulation are disrupted.

- There’s little evidence that exists around how hormonal contraceptives may impact the nutritional requirements of female cyclists.
- Menopausal women also have special nutritional considerations, particularly with regard to regulating body temperature, aiding sleep, reducing muscle protein breakdown, supporting bone health and potentially combatting a reduced tolerance to carbohydrates, although there is less evidence around this latter factor.

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Final Words

Thanks for taking the time to read this guide. We really hope you found it to be a useful resource to support your training and performance.

We're always looking for ways we can improve our resources, so please do get in touch at info@highnorth.co.uk if you have any feedback.

Wishing you all the best with your training and racing!

Tom Bell and Dr Emma Wilkins