2 Nutrition for Extreme Sports

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2.1 Introduction

It has been well established that sound nutrition can accelerate recovery, enhance adaptations to training and improve performance. Competing in extreme sports places stress on the body, and conducting activities in extreme environments can exacerbate the physiological stress on the competitor. Fortunately, scientific research in this area is growing, and we now have a range of nutritional strategies that can help the athlete competing in extreme sports in various ways.

The physiological and metabolic requirements of different extreme sports vary greatly; thus providing specific nutritional recommendations is problematic. For instance, certain extreme sports such as cliff diving and climbing have very different nutritional needs compared to ultra-endurance long-distance events such as adventure racing, mountaineering and ultra-distance running. Nevertheless, the aim of this chapter is to provide both generic nutritional guidelines and specific recommendations for special circumstances.

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2.2 General Nutritional Recommendations

2.2.1 Energy

Optimal dietary intake is essential for successful performance. Macronutrients consist of carbohydrates, proteins and fats and contribute to the majority of nutrients ingested. The manipulation of these both in terms of amounts and timing can provide athletes with a platform to aid performance dependent on the type of sport. Energy consumption must equal energy expenditure in order to achieve energy balance if the desired goal is weight maintenance. A negative or positive energy balance might be advantageous in certain situations where weight loss or muscle hypertrophy is required. General daily energy intake requirements are lower for females (1600–3700 kcal) than males (2900–5900 kcal); however this may vary due to athlete situation.

2.2.2 Carbohydrate

Carbohydrate (CHO) has four main roles in the body. The first is to act as a main energy source during high-intensity exercise in which glycogen (the stored form of carbohydrate) is broken down into glucose (glycogenolysis). Glucose is then used to create ATP through the process of glycolysis (oxidised to form water and carbon dioxide) [1]. CHO also helps to preserve important

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tissue proteins that are essential for muscular maintenance, repair and growth, provide an uninterrupted supply of fuel to the central nervous system as the brain metabolises blood glucose [2] and act as a metabolic primer for fat oxidation. The readily available carbohydrate sources are fairly limited (i.e. 1500–2000 kcal) and become a restrictive factor in the performance of prolonged sessions (>90 min) of submaximal or intermittent high-intensity exercise [2]. Thus adequate intake of carbohydrates prior, during and after exercise is essential for extreme sports lasting longer than 90 min. It should be noted that carbohydrate guidelines will differ depending on intensities and duration of activity undertaken.

2.2.2.1 Intensity

As intensity increases, so does the release of glucose from the liver to the active muscles. Stimulation in muscle glycogen utilisation also occurs as the energy increases. This can be determined via performing gas analysis and referring to the respiratory exchange ratio. If the RER rises above 1.0, then CHO becomes the primary source of energy production. Therefore, the higher the intensity, the more CHO will be needed to maintain that desired workload. Thus the extreme sports that have short sharp bursts will have a greater reliance upon carbohydrate for fuel.

2.2.2.2 Duration

As exercise duration increases, muscle glycogen decreases, causing fat catabolism to begin to furnish an increasing percentage of total energy. Therefore, a greater amount of CHO may be required prior to exercise if competing for long durations. Also, simple CHO such as glucose can be ingested during exercise to maintain supply of glycogen to the muscles. The type and timing of CHO are also very important. More specifically, CHO can be determined by their complexity (mono-, di- or polysaccharides) and by their glycaemic index (GI). Despite a lot of conflicting research, it is thought that lower GI foods are more advantageous prior to exercise as they lead to an increase in free fatty acids, better maintenance and slower release of plasma glycogen, resulting in more sustained carbohydrate availability during exercise [3]. It is also agreed that during and directly after exercise, high GI and simple CHOs are advantageous (glucose and sucrose) as they are broken down quicker via glycolysis and promote faster muscle glycogen recovery [2, 4].

The American College of Sports Medicine (ACSM) [5] recommends 6–10 g/kg body weight of CHO per day (ACSM, 2009). However, this may fluctuate dependent on the sport undertaken as specified in Table 2.1.

2.2.3 Protein

Protein (PRO) is made up of a combination of amino acids (AA). Some PRO can be synthesised within the body such as alanine, serine and

Table 2.1 CHO guidelines for extreme sports

Intensity/duration	Recommended CHO intake	Extreme sports
Low to moderate intensity and duration (<1 h)	5–7 g/kg/day	BMX Rock climbing Snowboarding/skiing Windsurfing Surfing
Endurance athletes (1–3 h of moderate to high intensity) Extreme conditions (3+ h of moderate to high intensity)	7–10 g/kg/day 10–12+ g/kg/day	Mountaineering Ice climbing Cross-country skiing Ironman triathlons
Pre-exercise meal	1–4 g/kg 1–4 h prior	
During moderate- to high-intensity exercise (>1 h)	0.5–1.0 g/kg/h	
Rapid postexercise recovery	1 g/kg immediately after exercise and repeated 2 h later	

Adapted from Burke et al. [6]

glutamic acid. However, there are many essential AA that we are unable to synthesise such as leucine, lysine and tryptophan. Therefore, it is important that adequate ingestion of protein from the daily diet is undertaken to maintain protein synthesis and adequate recovery.

PRO is used primarily to promote muscle fibre repair, regeneration and growth [7]. They can however also be utilised as an energy source if CHO and fat sources have reduced significantly. For most sports, this is not a desired outcome as it may lead to a decrease in AA available for recovery and regeneration [8]. Dependent on the discipline of extreme sport, the recommended daily intake and intake for recovery differ greatly. The ACSM [5] have recommended 1.2–1.7 g/kg/day and that this is done via dietary intake. For endurance athletes, 1.7 g/kg may not be needed if adequate fuel is ingested through CHO and fat. But for any sport that requires strength and power (e.g. BMX, snowboard freestyle or free running), more than 1.7 g/kg/day could be advantageous [5]. However, it has been suggested that there is no harm in ingesting more protein than this. For example, for some sports that require large energy intakes (~6400 kcal), as much as 2.5–3.2 g/kg of PRO may be necessary [7].

In order to utilise the dietary requirements, again, the timing of ingestion of protein is essential. Studies have shown that ingestion of protein immediately before exercise promotes a greater net protein balance than ingestion postexercise following resistance exercise (providing adequate CHO has been ingested) [5, 9]. It has also been reported that net protein uptake is increased when a combination of PRO and CHO is ingested oppose to either of them on their own [7]. Protein ingested after training is still advantageous and should be in a simple form such as whey as it is rapidly digestible.

2.2.4 Fat

Fat (lipids) is a necessary component of a normal diet for any athlete. Large amounts of fat can be stored in adipose tissue and thus can be readily available for prolonged exercise. Lipids also protect vital organs such as the heart, brain, liver and kidneys. They are an essential source of fat-soluble vitamins such as A, D, E and K and are important constituents of cell membranes. Cholesterol, which is a type of lipid, is a precursor for important hormones such as testosterone.

In accordance with the ACSM [5] guideline, fat consumption should range from 20 to 35 % of total energy intake across all intensities and durations. This should include approximately 10 % saturated, 10 % polyunsaturated and 10 % monounsaturated as well as including sources of essential fatty acids. Saturated fats should be avoided. For certain extreme sports such as mountaineering and extreme expedition-type events where competitors must carry their own food supplies, foods high in fat may be advantageous as they provide 9 kcal/g as opposed to carbohydrate and protein which provide 4 kcal/g. In these situations, where large energy expenditure is prevalent, foods high in fat can help maintain energy balance to an extent.

2.3 Weight Management

The principles of weight management remain the same regardless of the sport. Therefore this section will focus on general methods for weight gain or weight loss. Weight change is best done during the off-season or a period outside of competition to prevent any potential adverse effects on performance. For extreme sports such as rock climbing and ultra-endurance sports, a high power to weight ratio is desirable so competitors may want to manipulate body composition. Similarly, for other sports such as BMX, canoeing and white-water rafting, competitors may want to increase muscle mass and reduce body fat.

2.3.1 Weight Gain

Weight gain through increasing skeletal muscle mass (hypertrophy) is often advantageous in many sporting contexts and activities. To increase weight, an athlete must achieve a positive energy balance with muscle hypertrophy only occurring when muscle protein synthesis exceeds the rate of protein breakdown for a prolonged period of time [10]. The two principal determinants of skeletal muscle protein synthesis in adults are physical activity and nutrient availability [11].

Utilising protein ingestion with physical activity, particularly resistance exercise, promotes an optimal anabolic environment in the skeletal muscle compared to either stimulus alone [12]. The addition of protein ingestion following a bout of resistance exercise has repeatedly been shown to augment the stimulation of muscle protein synthesis, which over a period of resistance training with increased protein consumption can lead to muscular hypertrophy. The anabolic effects of nutrition are driven by the transfer and incorporation of amino acids captured from dietary protein sources into skeletal muscle proteins. The amino acid leucine has been highlighted to be particularly important in stimulating protein synthesis and appears to have a controlling influence over the activation of protein synthesis [13]. As such, rapidly digested leucine-rich proteins such as whey, in conjunction with resistance exercise, are advised for individuals wishing to increase muscle mass. In terms of protein quantity, 20–25 g of high-quality protein with at least 8–10 g of essential amino acids [14] has been shown to maximally potentiate exercise-induced rates of muscle protein synthesis in healthy young adults [15]. In total, athletes are recommended to consume ~1.3–1.8 $g.kg^{-1}.d^{-1}$, consumed as four meals while attempting to gain weight through increasing muscle mass [16]. It should be noted that these recommendations are dependent on training status and more protein should be consumed during periods of high-frequency/high-intensity training.

2.3.2 Weight Loss

Weight loss is not an uncommon goal for athletes and is often motivated by factors relating to performance issues. This usually involves weight loss either to enhance performance or for aesthetic reasons. Excess fat is often detrimental to performance of physical activities requiring the transfer of body mass either vertically (such as in jumping) or horizontally (such as in running). This is because it adds mass to the body without providing any additional capacity to produce force. Excess fat can also be detrimental to performance through increasing the metabolic cost of physical activity that requires movement of the total body mass.

Weight loss can occur when a negative energy balance is created. Thus, weight loss can be achieved by restricting energy intake, increasing the volume/intensity of training or, most often, a combination of both these strategies. It is important for athletes and coaches to recognise that with extreme energy restrictions, losses of both muscle and fat mass may adversely influence an athlete's performance [17]. Therefore, in most cases, it is important for an athlete to preserve their fat-free mass during periods of weight loss. There is a growing body of evidence suggesting that higher protein intakes during energy restriction can enhance the retention of fat-free mass [18, 19]. A reduction in dietary fat and carbohydrate may allow athletes to achieve higher protein intakes without the excessive restriction of a particular macronutrient. Current recommendations advise athletes aiming to achieve weight loss without losing fat-free mass to combine a moderate energy deficit (~500 $kcal.d^{-1}$) with the consumption of between ~1.8 and 2.0 $g.kg^{-1}.d^{-1}$ of protein in conjunction with performing resistance exercise [14].

2.4 Nutritional Issues and Challenges

2.4.1 Travel

It is not uncommon that extreme sports athletes may be frequent travellers due to the nature of their sport and competition; thus they may face frequent trips that may involve long travel times that can cause fatigue. Having access to nutritious balanced meals and adequate fluid can be challenging; however, ample pre-planning meal, snack and fluid arrangements can

Table 2.2 Nutritional strategies for travel

Issue	Detail	Strategy
Infection and illness	Travelling poses the risk of infection and gastrointestinal disturbance when travelling (more so if travelling abroad)	Using antibacterial hand gels and washing hands often can minimise some risk. In addition the use of probiotics can also be useful in some instances
Catering	Different hotels and kitchens have their own way of preparing meals that may be very different to expectations	Communication with menu plans and possibly recipes and specific snack items may be useful
Food and water hygiene	In some countries it is ill advised to drink tap water, and foods such as fruit, vegetables, salads and ice cubes could pose a risk	Stick to drinking sealed bottled water and avoid swallowing water when brushing teeth; showering and ensuring food is washed with clean water that is not contaminated
Eating on the move	Travel poses uncertain issues such as delay and availability of food on the move; therefore the team should ensure that snacks and meals are pre-planned	Communication with travel companies, hotels and pre-packing food items are important as problems such as delays can pose a problem

Adapted from Ranchordas et al. [21]

enhance an athlete's dietary preparation when travelling [20]). Table 2.2 provides a practical summary of key dietary strategies that can help support teams cope with challenging travel demands.

2.5 Fluid and Electrolyte Requirements

2.5.1 Sweat Rates and Electrolytes

Exercise is associated with high rates of metabolic heat production, eliciting high rates of sweat secretion in order to attenuate the rise in body temperature that would otherwise occur. If exercise is prolonged, this leads to progressive hypohydration and a loss of electrolytes, particularly in hot environments where sweat rates may exceed 2 l/h [22].

Significant hypohydration can occur during many types of exercise activity and poses a challenge to both an individual's performance and health. Hypohydration can have a negative impact on exercise outcomes through impairing thermoregulation and performance of prolonged aerobic exercise [23], cognitive function [24] and gastric emptying and comfort [25]. These performance impairments can be detected when fluid losses are as low as 1.8 % of body mass [22]. A body mass loss of more than 4 % during exercise may lead to heat exhaustion and heat illness [22]. Even in winter sports environments, where sweat rates are expected to be lower, fluid loss can be significant [26]. Nordic skiers competing in 15–30-km races can typically lose 2–3 % of body mass, and collegiate cross-country skiers lost 1.8 % of body mass after 90 min of ski training [27]. Thus, strategies to minimise the degree of hypohydration should be undertaken before, during (if possible) and in recovery from exercise activities.

2.5.2 Measuring Hydration and Electrolyte Status

Sweat rates and electrolyte losses can vary widely amongst different individuals and between different activities under the same environmental conditions. Therefore, it is difficult to accurately prescribe fluid and electrolyte intakes without knowledge of individual sweat rates under the specific environmental conditions. Hydration status can be monitored by employing simple urine and body mass measurements. Changes in body mass can reflect sweat losses during exercise and can be used to calculate individual fluid replacement needs for specific exercise activities and environmental conditions. Urine osmolality also provides a clear indication of hydration status and can be measured quickly and simply using a portable osmometer. A urine osmolality of 100–300 mOsmol/kg indicates that an individual is well hydrated. Values of over 900 mOsmol/kg indicate that an individual is relatively dehydrated. Portable urine osmometers can be useful to assess hydration status in the field as they are small, reliable and convenient and thus can be a good tool to monitor hydration status objectively.

Accurately measuring electrolyte losses is a more challenging, as the composition of sweat is difficult to measure and the methods such as sweat patch testing have poor reliability. Electrolyte losses vary greatly between individuals but also vary with changing sweat rates over time [28]. The major electrolytes lost in sweat are sodium and chloride. These are the major ions of the extracellular space; therefore, the replacement of these ions, especially sodium, should be a priority. The perception of thirst as the signal to drink is unreliable. This is because a considerable degree of dehydration, sufficient enough to impair athletic performance, can occur before the desire to drink is evident [29]. The sensation of thirst results increases the secretion of the antidiuretic hormone from the posterior pituitary gland, which acts on the kidneys to reduce urine excretion. However, thirst is quickly alleviated through drinking fluid before a significant amount of fluid is absorbed in the gut [22]. Thus, the use of thirst alone should not be used as indicator of fluid balance.

2.5.3 Constituents of Fluid Ingested

Electrolytes play a key role in promoting postexercise rehydration. This was first highlighted by Costill and Sparks [30], who showed that the ingestion of a glucose-electrolyte solution after a relatively severe degree of hypohydration (4 % of the pre-exercise body mass) resulted in a greater restoration of plasma volume than water alone. A higher urine output was also observed in the water trial. The ingestion of drinks containing sodium following exercise promotes rapid fluid absorption in the small intestine, allows the plasma sodium concentration to remain elevated during rehydration and helps maintain thirst while delaying the stimulation of urine production. Drinks containing multiple transportable carbohydrates such as glucose and fructose can also aid hydration through enhancing gastric emptying rates, improving the delivery of fluid consumption compared to a single carbohydrate drink (this is covered in more detail in the carbohydrate supplements section) [31]. The addition of carbohydrate can also make the drink more palatable, aiding the rehydration process.

Gonzales-Alonso et al. [32] confirmed that a dilute carbohydrate-electrolyte solution (60 g/l carbohydrate, 20 mmol.l^{-1} Na+, 3 mmol.l^{-1} K+) was more effective in promoting postexercise rehydration than either plain water or a low-electrolyte diet cola. The difference between the drinks was primarily the volume of urine produced. As previously mentioned, individual sodium content of sweat varies widely, and no single formulation will meet requirements for all individuals in all situations. The upper end of the normal range for sodium concentration (80 mmol.l^{-1}), however, is similar to the sodium concentration of many commercially produced oral rehydration solutions intended for use in the treatment of diarrhoea-induced dehydration. In contrast, the sodium content of most sports drinks is in the range of 10–30 mmol.l^{-1}. Most commonly consumed soft drinks contain virtually no sodium, and these drinks are, therefore, unsuitable for rehydration. The problem with high sodium concentrations is that this may exert a negative effect on taste, resulting in reduced consumption. Therefore, it is important that a balance between electrolyte content and palatability is achieved.

2.5.3.1 Before Exercise

Beginning exercise in a hypohydrated state can have a negative impact on performance of high-intensity [33] and endurance exercise [34]. Thus, the main goal of fluid intake before exercise is to begin in a euhydrated state with normal plasma electrolyte levels. This can be achieved through consuming a balanced diet and drinking adequate fluid during a period 24 h before exercise event. Consuming a further 500 ml of fluid around 2 h before exercise helps promote adequate hydration and allow time for secretion of excess ingested water [5]. However, if an individual has suffered from substantial fluid loss and only has a short recovery period before a subsequent bout of exercise, then an aggressive prehydration strategy may be merited to establish euhydration.

Attempting to hyperhydrate before exercise will greatly increase the risk of having to void during competition and provides no clear physiological or performance advantage over euhydration [35, 36]. In addition, hyperhydration can substantially dilute and lower plasma sodium [37, 38] before starting exercise and therefore increase the risk of dilutional hyponatraemia, especially if fluids are aggressively replaced during exercise [39].

2.5.3.2 During Exercise

Extreme sports vary in nature and some in some sports; there may not be an opportunity to take on some fluids during exercise, whereas in other sports this may not be a problem. Nevertheless, if fluid intake during exercise is possible, then the main goal is to prevent excessive dehydration (>1.8 % body mass loss from fluid loss) and excessive changes in electrolyte balance that could impair performance.

During exercise, especially in a hot environment, dehydration can only be avoided by matching sweat loss with fluid consumption. However, sweat rates during strenuous exercise in the heat can be as high as 2–3 l/h, and a volume of ingested fluid of more than about 1 l feels uncomfortable in the stomach for most people when exercising. Therefore, achieving fluid intakes that match sweat losses during exercise is often not practical. In these situations, it may be necessary to rehydrate after exercise, especially if there is a second bout of exercise later that day or the day after (e.g. for sports such as adventure racing and expedition-type activities).

Fluid intake during strenuous exercise lasting less than 30 min in duration offers no advantage. Gastric emptying is inhibited at high work rates, and insignificant amounts of fluid are absorbed during exercise of short duration. For most individuals exercising for 30–60 min in moderate ambient conditions, an appropriate drink is cool water. For exercise lasting more than 1 h or exercise in hot and humid conditions, consumption of a drink containing carbohydrates and electrolytes is warranted. Fluid ingestion during prolonged exercise provides an opportunity for exogenous fuel consumption as well as helping to maintain plasma volume and preventing dehydration. The replacement of electrolytes lost in sweat can normally wait until the postexercise recovery period as stated previously. Individuals should become accustomed to consuming fluid at regular intervals (with or without thirst) during training sessions so that they do not experience discomfort during competition.

2.5.3.3 Postexercise

After exercise the main goal of fluid intake is to fully replace fluid electrolytes lost during exercise and return to a euhydrated state. As previously mentioned, this is particularly important when exercise is prolonged and takes place in a hot environment or when consuming fluid during exercise is not possible.

Even when fluids are available during longer exercise periods, the volume ingested is rarely sufficient to match the rate of sweat loss, and some degree of fluid deficit usually accompanies exercise. Replacement of these losses must be achieved in the recovery period after exercise ends before the next bout of exercise is undertaken.

Fluid intake also comes from food consumption. Some foods, especially plant material, have high water content. In fact, water in food makes a major contribution to total body fluid intake. Water is also produced internally (metabolic water) from the catabolism of water, fat and protein. For example, in the complete oxidation of one molecule of glucose, six molecules of carbon dioxide and six molecules of water are produced. Therefore, consuming food with fluid following exercise is recommended to aid rehydration while also providing essential electrolyte replenishment.

On the completion of exercise, individuals are encouraged to consume a volume of fluid equivalent to 150 % of sweat loss (i.e. 1.5 l of fluid consumed during recovery from exercise for every kilogram of body mass loss during exercise) within 6 h after exercise. This is to account for continued fluid loss from sweat and urine following the cessation of exercise.

2.6 Special Nutrition Considerations for Extreme Sports: Practical Recommendations

Individuals should attempt to begin all exercise sessions in a euhydrated state. Taking current recommendations into consideration [5, 40], individuals participating in extreme sports where significant sweat losses have occurred should ingest a volume of fluid substantially greater than the volume of sweat lost. This should equate to around 150 % of sweat loss over a 6-h period in order to account for continued sweat and urine losses following the cessation of exercise. This clearly requires knowledge of sweat loss, and a reasonable estimate can be obtained from changes in body mass. An effective rehydration drink intended for consumption after exercise should be both effective and palatable.

For optimal hydration during prolonged exercise, particularly in hot and humid environments, the addition of sodium (10–30 mmol.l^{-1}) in conjunction with multiple carbohydrates can aid fluid uptake, provide an exogenous fuel source and prevent excessive hypohydration. The ideal drink for fluid replacement is one that tastes good to the individual, does not cause gastrointestinal discomfort when consumed in large volumes, promotes gastric emptying and fluid absorption to help maintain the extracellular volume and provides some energy to the muscle in the form of carbohydrate.

2.6.1 Nutritional Strategies for Cooling

The rise in core body temperature observed when exercise is performed in hot environmental conditions is associated with reduced motor output during self-paced exercise [41, 42], as well as the termination of exercise during time to exhaustion protocols [43, 44]. The central nervous system is thought to reduce motor output following elevations in core temperature and terminate exercise once critically high internal temperatures are attained, in an attempt to limit the development of catastrophic heat illness [45].

The subjective perception of effort is an important consideration. If the exercise feels hard, the duration will often be cut short and adherence is likely to be poor. It is well recognised that the subjective rating of perceived exertion is higher when exercise is performed in warm environments than in cool environments [46] and is also increased by even moderate levels of hypohydration.

Total body water can have a critical influence on thermoregulation and exercise performance in the heat. Total body water usually remains relatively constant [47]; however, physical exercise and heat exposure will increase water flux to support thermoregulation [48]. In a hot environment, sweat evaporation is the primary avenue for dissipating body heat absorbed from the environment or produced by the exercising muscle. Therefore, the most notable effect of exercise in a hot climate is increased fluid loss.

Hypohydration increases heat storage by reducing skin blood flow and sweating rate responses for a given core temperature. Hypohydration lowers both intracellular and extracellular fluid volumes. It also results in plasma hypertonicity, with the potential effect being greater in warm environments.

Pre-exercise cooling is a strategy for improving prolonged exercise performance in the heat. This is based on evidence that reducing initial core temperature allows for a greater heat storage capacity during exercise, in turn prolonging the onset of hyperthermia-induced fatigue [49]. The ingestion of cold fluid or ice slurries has been suggested as nutritional strategies that could be used for internal cooling. Indeed, ingesting cold water (4 °C) versus warm water (37 °C) before and during exercise in hot environments prolonged cycling time to exhaustion by 23 ± 6 % [50]. The pre-exercise ingestion of ice slurry (−1 °C) has been shown to be even more effective compared to cold water (4 °C) at lowering rectal temperature and extended the ensuing running time to exhaustion by 19 ± 6 % [51]. The ingestion of substantial volumes (6.5–7.5 $g.kg^{-1}$ body mass) of ice slurry in 30 min prior to exercise has repeatedly been shown to improve endurance capacity and performance during exercise [51–54] and appears to be the most effective nutritional strategy for cooling.

2.7 Supplements and Ergogenic Aids

The use of sports foods and dietary supplements amongst athletes is widespread; however, many products are not effective and lack evidence for improving soccer performance. Moreover, many supplements have been found to be contaminated and could increase the risk of a positive doping test; thus athletes who are subjected to anti-doping testing should ensure that dietary supplements are batch tested for contamination before use. This section provides an overview of certain supplements that may be beneficial for extreme sports.

2.7.1 Creatine

Creatine supplementation increases intramuscular phosphocreatine stores and appears to enhance performance in activities that primarily involve repeated short bouts of high-intensity exercise that require energy from the ATP-PC energy system. Therefore, the rationale for using creatine supplementation to enhance performance in extreme sports such as downhill mountain biking, skateboarding, BMX and other extreme activities with short sharp bursts has merit considering that these activities consist of movements that predominately use the ATP-PC energy system over prolonged durations. The majority of the early research that has examined the effectiveness of creatine supplementation suggests using a loading phase of 5 g of creatine 4 times per day for the initial 5 days followed by a maintenance dose of 5 g/day to maximise phosphocreatine stores and enhance performance [55]. Creatine loading may not be necessary if quick loading is not essential, and in this case a dose of 5 g either once daily or twice daily is adequate. Creatine seems to be more effective when taken with high GI carbohydrates as the increase in blood glucose and subsequently insulin plays a role in the absorption of creatine within the muscle so competitors are encouraged to take the 5-g dose of creatine with approximately 40 g of high GI carbohydrate [56].

2.7.2 Beta-Alanine

Supplementing the diet with beta-alanine may have an ergogenic effect on high-intensity exercise, particularly exercise capacity, in activities lasting between 1 and 4 min [57, 58]. Thus extreme sports that fall within this range such as skateboarding, BMX, downhill mountain biking and surfing may benefit from beta-alanine supplementation. The rate of carnosine synthesis in the human skeletal muscle is limited by the availability of beta-alanine from the diet [59]. Although several potential roles have been ascribed to carnosine in the skeletal muscle, its main role has been identified as an intramuscular pH buffer due to its molecular structure [60, 61].

High-intensity exercise can lead to an accumulation of hydrogen ions (H+) in the skeletal muscle, causing a reduction in the intramuscular pH. Under normal resting conditions, intramuscular pH is around 7.0. However, during high-intensity exercise, muscle pH may fall to as low as 6.0 [62]. This can result in reduced muscle function and force generation, contributing to fatigue.

Carnosine molecules contain an imidazole ring that allows it to lend itself as an intracellular buffer through directly accepting and buffering H+ ions [63]. With a pKa of 6.83 and its high concentration in the muscle, specifically fast-twitch fibres [59], carnosine can act as a powerful immediate H+ buffering agent [64]. A higher muscle buffer value may benefit prolonged high-intensity exercise performance by allowing for a higher accumulation of H+ in the muscle before reaching a limiting muscle pH.

Supplementing the diet with 6.4 g of β-alanine per day for 4 weeks has been shown to increase carnosine concentrations in the skeletal muscle by ~60 % [60] and by ~80 % when supplementing for 10 weeks with the same quantity [58]. Stellingwerff and colleagues [65] suggested that for a desired increase (~50 %) in muscle carnosine, a total of ~230 g of beta-alanine must be taken within a daily consumption range of 1.6–6.4 $g.d^{-1}$. Higher doses are not advised due to the potential for symptoms of paresthesia [59]. Additionally, once muscle carnosine is augmented, the washout period is very slow at ~2 % per week [65].

2.7.3 Dietary Nitrates

Over recent years, the use of dietary nitrates has become popular in sport, and there are now supplements such as concentrated beetroot shots, nitrate-containing gels and bars available that are purported to enhance performance. Various studies have found that approximately 8.4 mmol of dietary nitrate can improve tolerance to endurance exercise, reduce the oxygen cost of exercise and increase time to exhaustion which can be beneficial for extreme sports that have a large endurance exercise component such as ultra-endurance exercise [66, 67]. The type of supplement used in these studies has been mainly concentrated beetroot shots which are commercially available. One study has investigated the effects of dietary nitrate supplementation in hypoxic conditions. Kelly and co-workers [68] investigated the effects of 140 ml of concentrated beetroot juice that contained approximately 8.4 mmol of nitrate and a placebo ingested for 3 days prior to a cycling performance test in 12 healthy participants during normoxia (20.9 % O2) and hypoxia (13.1 % O2). It was found that in hypoxia, nitrate supplementation enhanced VO2 kinetics during moderate-intensity exercise and improved severe-intensity exercise tolerance. These findings suggest that nitrate supplementation may have important benefits for individuals exercising in conditions at high altitude; thus competitors in extreme sports such as high-altitude climbing and expedition-type events should consider the use of nitrate supplementation.

2.7.4 Caffeine

Caffeine has been studied extensively over the last two decades, and numerous studies have demonstrated that caffeine can enhance endurance performance [69, 70]. The use of caffeine for performance has several benefits including the mobilisation of fatty acids to enhance fuel use, changes to muscle contractility, stimulation of the central nervous system and stimulation of the release and activity of adrenaline [71].

For extreme sports that are characterised by very long distances where athletes often choose to go without sleep for a period of greater than 24 h while competing in events such as expeditions, caffeine can be used by competitors to help them stay awake and enhance performance. When taken in low to moderate doses (3–6 $mg.kg^{-1}$), caffeine is effective for enhancing endurance performance [69, 70], and it has been demonstrated that caffeine can enhance vigilance during bouts of extended exhaustive exercise, as well as periods of sustained sleep deprivation [72–74]. It should be noted that the scientific literature does not support the theory of caffeine-induced diuresis during exercise or detrimental effects on fluid balance that would negatively affect performance; therefore, caffeine use should be considered by extreme sports athletes.

2.7.5 Carbohydrate Supplements

Sports drinks, gels and bars are a convenient and portable source of carbohydrate that can be consumed during exercise. The carbohydrate content in these products is typically derived from glucose and dextrose, and numerous studies have found that sports drinks, gels and bars can prolong endurance performance [75–77]. More recently, however, there have been developments regarding the type of carbohydrate and its effects on endurance performance. Currell and

Jeukendrup [78] found that sports drinks containing glucose and fructose in a ratio of 2:1 led to an 8 % improvement in cycling time-trial performance compared to ingestion of glucose alone. These findings have since been replicated and furthered in several other studies [31, 79, 80] which have demonstrated that sports drinks and gels containing multiple transportable carbohydrates (i.e. glucose and fructose), when ingested at high rates, can be beneficial during endurance sports in which the duration of exercise is 3 h or more. For extreme sports lasting longer than 2 h, it may be beneficial for competitors to take on sports drinks, gels and bars that contain multiple transportable carbohydrates in the form of glucose and fructose. Supplements that provide 60–90 $g.h^{-1}$ of multiple transportable carbohydrates should be consumed during prolonged exercise. Competitors should practise feeding strategies during training to ensure that these carbohydrate doses are well tolerated. Moreover, due to individual preferences, certain competitors may prefer taking carbohydrate supplements in the form of a gel or bar as opposed to a drink.

2.7.6 Contamination of Supplements

The sports food and dietary supplement market is saturated with various purportedly ergogenic aids to enhance strength, speed, endurance and recovery. However, few are substantiated by convincing scientific evidence. Some supplements reviewed in this chapter such as carbohydrates and caffeine can enhance performance in extreme sports. However, it should be recognised that nutritional supplements can be a source of contamination and, hence, a positive doping test. Various studies have shown that commercially available dietary supplements and ergogenic aids available over the Internet or over the counter are contaminated with substances banned on the WADA list of prohibited substances [81, 82]. It is important that extreme sports athletes take supplements that are evidence based and free from contamination; thus it is a good practice to seek sports nutrition advice from a qualified professional, especially if the athlete is subjected to drug testing. Moreover, there are laboratories that offer the facility to test dietary supplements for contaminants that are in the WADA list of prohibited substances; therefore, athletes should use this facility to ensure that supplements are safe.

Conclusion

The nutritional requirements for extreme sports vary greatly depending on the type of sport, the environmental conditions and the duration of the activity. Typically, for extreme sports that are longer in duration such as mountaineering, adventure racing, ultra-endurance activities and expedition-type events, the energy demands are much greater, and thus competitors should plan their dietary needs in advance. An inadequate diet and poor fuelling strategies can impair performance and increase the risk of injury and illness during events. Appropriate hydration strategies need to be planned in advance if taking part in extreme environments, and bespoke cooling strategies such as ice slurry ingestion can be used in the heat. Supplements such as caffeine, carbohydrate and dietary nitrates can be used to enhance performance although competitors should check safety and ensure they are batch tested and safe products.

References

1. Jeukendrup AE. Carbohydrate intake during exercise and performance. Nutrition. 2004;20(7):669–77.
2. Burke LM, Kiens B, Ivy JL. Carbohydrates and fat for training and recovery. J Sports Sci. 2004;22(1):15–30.
3. O'Reilly J, Wong SH, Chen Y. Glycaemic index, glycaemic load and exercise performance. Sports Med. 2010;40(1):27–39.
4. Blom PC, Hostmark AT, Vaage O, Kardel KR, Maehlum S. Effect of different post-exercise sugar diets on the rate of muscle glycogen synthesis. Med Sci Sports Exerci. 1987;19(5):491–6.
5. Rodriguez NR, Dimarco NM, Langley S. American Dietetic Association, Dietitians of Canada and American College of Sports Medicine: nutrition and athletic performance. Position of the American Dietetic Association, Dietitians of Canada, and the American College of Sports Medicine: nutrition and

athletic performance. J Am Diet Assoc. 2009;109(3):509–27.
6. Burke LM, Cox GR, Cummings NK, Desbrow B. Guidelines for daily carbohydrate intake. Sports Med. 2001;31(4):267–99.
7. Tipton KD, Wolfe RR. Protein and amino acids for athletes. J Sports Sci. 2004;22(1):65–79.
8. Tarnopolsky M. Protein requirements for endurance athletes. Nutrition. 2004;20(7):662–8.
9. Tipton KD, Rasmussen BB, Miller SL, Wolf SE, Owens-Stovall SK, Petrini BE, Wolfe RR. Timing of amino acid-carbohydrate ingestion alters anabolic response of muscle to resistance exercise. Am J Physiol Endocrinol Metab. 2001;281(2):197–206.
10. Koopman R, Saris WH, Wagenmakers AJ, Van Loon LJ. Nutritional interventions to promote post-exercise muscle protein synthesis. Sports Med. 2007;37(10):895–906.
11. Atherton PJ, Smith K. Muscle protein synthesis in response to nutrition and exercise. J Physiol. 2012;590(5):1049–57.
12. Breen L, Phillips SM. Nutrient interaction for optimal protein anabolism in resistance exercise. Curr Opin Clin Nutr Metab Care. 2012;15(3):226–32.
13. Volpi E, Kobayashi H, Sheffield-Moore M, Mittendorfer B, Wolfe RR. Essential amino acids are primarily responsible for the amino acid stimulation of muscle protein anabolism in healthy elderly adults. Am J Clin Nutr. 2003;78(2):250–8.
14. Phillips SM. The science of muscle hypertrophy: making dietary protein count. Proceedings Nutr Society. 2011;70(01):100–3.
15. Moore DR, Robinson MJ, Fry JL, Tang JE, Glover EI, Wilkinson SB, Prior T, Tarnopolsky MA, Phillips SM. Ingested protein dose response of muscle and albumin protein synthesis after resistance exercise in young men. Am J Clin Nutr. 2009;89(1):161–8.
16. Phillips SM, Van Loon LJ. Dietary protein for athletes: from requirements to optimum adaptation. J Sports Sci. 2011;29 Suppl 1:29–38.
17. Murphy CH, Hector AJ, Phillips SM. Considerations for protein intake in managing weight loss in athletes. Euro J of Sport Sci. 2014:1–8. [Ahead-of-Print].
18. Helms ER, Zinn C, Rowlands DS, Brown SR. A systematic review of dietary protein during caloric restriction in resistance trained lean athletes: a case for higher intakes. Int J Sport Nutr Exerc Metab. 2014;24(2):127–38.
19. Josse AR, Atkinson SA, Tarnopolsky MA, Phillips SM. Increased consumption of dairy foods and protein during diet- and exercise-induced weight loss promotes fat mass loss and lean mass gain in overweight and obese premenopausal women. J Nutr. 2011;141(9):1626–34.
20. Ranchordas MK. Nutrition for Adventure Racing. Sports Med. 2012;42(11):915–27.
21. Ranchordas MK, Rogerson D, Ruddock A, Killer S, Winter EM. Nutrition for tennis: practical recommendations. J Sport Sci Med. 2013;12(2):211–24.
22. Maughan R, Noakes T. Fluid replacement and exercise stress. Sports Med. 1991;12(1):16–31.
23. Sawka MN, Pandolf KB. Effects of body water loss on physiological function and exercise performance. Perspectives Exerc Sci Sports Med. 1990;3:1–38.
24. Gopinathan P, Pichan G, Sharma V. Role of dehydration in heat stress-induced variations in mental performance. Archives Environ Health Int J. 1988;43(1):15–7.
25. Rehrer NJ, Beckers EJ, Brouns F, Ten Hoor F, Saris WH. Effects of dehydration on gastric emptying and gastrointestinal distress while running. Med Sci Sports Exerc. 1990;22(6):790–5.
26. O'brien C, Young AJ, Sawka MN, 1. Hypohydration and thermoregulation in cold air. J Appl Physiol (Bethesda, Md: 1985). 1998;84(1):185–9.
27. Seifert JG, Luetkemeier MJ, White AT, Mino LM. The physiological effects of beverage ingestion during cross country ski training in elite collegiate skiers. Can J Appl Physiol. 1998;23(1):66–73.
28. Maughan R, Shirreffs S. Rehydration and recovery after exercise. Sci Sports. 2004;19(5):234–8.
29. Maughan RJ, Shirreffs SM. Nutrition for sports performance: issues and opportunities. Proceedings Nutr Society. 2012;71(01):112–9.
30. Costill D, Sparks K. Rapid fluid replacement for thermal dehydration. Heart. 1973;3:4.
31. Jeukendrup A, Moseley L. Multiple transportable carbohydrates enhance gastric emptying and fluid delivery. Scand J Med Sci Sports. 2010;20(1):112–21.
32. Gonzalez-Alonso J, Heaps C, Coyle E. Rehydration after exercise with common beverages and water. Int J Sports Med. 1992;13(05):399–406.
33. Goulet ED, Lamontagne-Lacasse M, Gigou P, Kenefick RW, Ely BR, Cheuvront S. Pre-exercise hypohydration effects on jumping ability and muscle strength, endurance and anaerobic capacity: a meta-analysis; 1681: Board#118 June 23:30 PM-5:00 PM. Med Sci Sports Exerc. 2010;42(5):362.
34. Gigou P, Lamontagne-Lacasse M, Goulet ED. Meta-analysis of the effects of pre-exercise hypohydration on endurance performance, lactate threshold and Vo2 max: 1679: Board# 116 June 23:30 PM-5:00 PM. Med Sci Sports Exerc. 2010;42(5):361–2.
35. Latzka WA, Sawka MN, Montain SJ, Skrinar GS, Fielding RA, Matott RP, Pandolf KB, 6. Hyperhydration: tolerance and cardiovascular effects during uncompensable exercise-heat stress. J Appl Physiol (Bethesda, Md: 1985). 1998;84(6):1858–64.
36. Latzka WA, Sawka MN, Montain SJ, Skrinar GS, Fielding RA, Matott RP, Pandolf KB. Hyperhydration: thermoregulatory effects during compensable exercise-heat stress. J Appl Physiol (Bethesda, Md: 1985). 1997;83(3):860–6.
37. O'brien C, Freund BJ, Young AJ, Sawka MN. Glycerol hyperhydration: physiological responses during cold-air exposure. J Appl Physiol (Bethesda, Md: 1985). 2005;99(2):515–21.
38. Freund BJ, Montain SJ, Deluca JP, Pandolf KB, Valeri CR. Glycerol hyperhydration: hormonal, renal, and vascular fluid responses. J Appl Physiol. 1995;79:2069–77.

39. Montain SJ, Cheuvront SN, Sawka MN. Exercise associated hyponatraemia: quantitative analysis to understand the aetiology. Br J Sports Med. 2006;40(2):98–105.
40. Kreider RB, Wilborn CD, Taylor L, Campbell B, Almada AL, Collins R, Cooke M, Earnest CP, Greenwood M, Kalman DS. ISSN exercise & sport nutrition review: research & recommendations. J Int Soc Sports Nutr. 2010;7(7):2–43.
41. Marino FE. Methods, advantages, and limitations of body cooling for exercise performance. Br J Sports Med. 2002;36(2):89–94.
42. Tucker R, Marle T, Lambert EV, Noakes TD. The rate of heat storage mediates an anticipatory reduction in exercise intensity during cycling at a fixed rating of perceived exertion. J Physiol. 2006;574(3):905–15.
43. Cheung SS, Mclellan TM, 5. Heat acclimation, aerobic fitness, and hydration effects on tolerance during uncompensable heat stress. J Appl Physiol (Bethesda, Md: 1985). 1998;84:1731–9.
44. Gonzalez-Alonso J, Teller C, Andersen SL, Jensen FB, Hyldig T, Nielsen B, 3. Influence of body temperature on the development of fatigue during prolonged exercise in the heat. J Appl Physiol (Bethesda, Md: 1985). 1999;86(3):1032–9.
45. Cheung SS. Hyperthermia and voluntary exhaustion: integrating models and future challenges. Appl Physiol Nutr Metab. 2007;32(4):808–17.
46. Galloway SD, Maughan RJ. Effects of ambient temperature on the capacity to perform prolonged cycle exercise in man. Med Sci Sports Exerc. 1997;29(9):1240–9.
47. Sawka MN, Coyle EF. Influence of body water and blood volume on thermoregulation and exercise performance in the heat. Exerc Sport Sci Rev. 1999;27(1):167–218.
48. Serwah N, Marino F. The combined effects of hydration and exercise heat stress on choice reaction time. J Sci Med Sport. 2006;9(1):157–64.
49. Marino FE, Mbambo Z, Kortekaas E, Wilson G, Lambert MI, Noakes TD, Dennis SC. Advantages of smaller body mass during distance running in warm, humid environments. Pflugers Arch. 2000;441(2–3):359–67.
50. Lee J, Shirreffs SM, Maughan RJ. Cold drink ingestion improves exercise endurance capacity in the heat. Med Sci Sports Exerc. 2008;40(9):1637–44.
51. Siegel R, Mate J, Brearley MB, Watson G, Nosaka K, Laursen PB. Ice slurry ingestion increases core temperature capacity and running time in the heat. Med Sci Sports Exerc. 2010;42(4):717–25.
52. Siegel R, Maté J, Watson G, Nosaka K, Laursen PB. Pre-cooling with ice slurry ingestion leads to similar run times to exhaustion in the heat as cold water immersion. J Sports Sci. 2012;30(2):155–65.
53. Burdon CA, Hoon MW, Johnson NA, Chapman PG, O'connor HT. The effect of ice slushy ingestion and mouthwash on thermoregulation and endurance performance in the heat. Int J Sport Nutr Exerc Metab. 2013;23:458–69.
54. Ihsan M, Landers G, Brearley M, Peeling P. Beneficial effects of ice ingestion as a precooling strategy on 40-km cycling time-trial performance. Int J Sports Physiol Perform. 2010;5(2):140–51.
55. Kreider RB. Effects of creatine supplementation on performance and training adaptations. Mol Cell Biochem. 2003;244(1-2):89–94.
56. Volek JS, Rawson ES. Scientific basis and practical aspects of creatine supplementation for athletes. Nutrition. 2004;20(7-8):609–14.
57. Sale C, Saunders B, Harris RC. Effect of beta-alanine supplementation on muscle carnosine concentrations and exercise performance. Amino Acids. 2010;39(2):321–33.
58. Hill CA, Harris RC, Kim HJ, Harris BD, Sale C, Boobis LH, Kim CK, Wise JA. Influence of β-alanine supplementation on skeletal muscle carnosine concentrations and high intensity cycling capacity. Amino Acids. 2007;32:225–33.
59. Harris RC, Tallon MJ, Dunnett M, Boobis LH, Coackley J, Kim HJ, Fallowfield JL, Hill CA, Sale C, Wise JA. The absorption of orally supplied β-alanine and its effect on muscle carnosine synthesis in human vastus lateralis. Amino Acids. 2006;30:279–89.
60. Bate-Smith EC. The Buffering of muscle in rigour: protein, phosphate and carnosine. J Physiol. 1938;92:336–43.
61. Hobson RM, Saunders B, Ball G, Harris R, Sale C. Effects of β-alanine supplementation on exercise performance: a meta-analysis. Amino Acids. 2012;43(1):25–37.
62. Pan J, Hamm J, Hetherington H, Rothman D, Shulman R. Correlation of lactate and pH in human skeletal muscle after exercise by 1H NMR. Magn Reson Med. 1991;20(1):57–65.
63. Begum G, Cuncliffe A, Leveritt M. Physiological role of carnosine in contracting muscle. Int J Sport Nutr Exerc Metab. 2005;15(5):493.
64. Vanthienen R, Vanproeyen K, Vanden-Eynde B, Puype K, Lefere T, Hespel P. β-alanine improves sprint performance in endurance cycling. Med Sci Sport Exerc. 2009;41:898–903.
65. Stellingwerff T, Decombaz J, Harris RC, Boesch C. Optimizing human in vivo dosing and delivery of β-alanine supplements for muscle carnosine synthesis. Amino Acids. 2012;43(1):57–65.
66. Bescos R, Sureda A, Tur JA, Pons A. The effect of nitric-oxide-related supplements on human performance. Sports Med. 2012;42(2):99–117.
67. Jones AM. Influence of dietary nitrate on the physiological determinants of exercise performance: a critical review. Appl Physiol Nutr Metab. 2014;39(9):1019–28.
68. Kelly J, Vanhatalo A, Bailey SJ, Wylie LJ, Tucker C, List S, Winyard PG, Jones AM. Dietary nitrate supplementation: effects on plasma nitrite and pulmonary O2 uptake dynamics during exercise in hypoxia and normoxia. Am J Physiol Regul Integr Comp Physiol. 2014;307(7):920–30.
69. Pasman W, Van Baak M, Jeukendrup A, De Haan A. The effect of different dosages of caffeine on

endurance performance time. Int J Sports Med. 1995;16(4):225–30.
70. Bridge C, Jones M. The effect of caffeine ingestion on 8 km run performance in a field setting. J Sports Sci. 2006;24(4):433–9.
71. Burke L. Practical Sports Nutrition. Leeds: Human Kinetics; 2007.
72. Scott JPR, Mcnaughton L. Sleep deprivation, energy expenditure and cardiorespiratory function. Int J Sports Med. 2004;25(6):421–6.
73. Mclellan TM, Kamimori GH, Bell DG, Smith IF, Johnson D, Belenky G. Caffeine maintains vigilance and marksmanship in simulated urban operations with sleep deprivation. Aviat Space Environ Med. 2005;76(1):39–45.
74. Mclellan TM, Kamimori GH, Voss DM, Bell DG, Cole KG, Johnson D. Caffeine maintains vigilance and improves run times during night operations for special forces. Aviat Space Environ Med. 2005; 76(7I):647–54.
75. Campbell C, Prince D, Braun M, Applegate E, Casazza GA. Carbohydrate-supplement form and exercise performance. Int J Sport Nutr Exerc Metab. 2008;18(2):179–90.
76. Saunders MJ, Luden ND, Herrick JE. Consumption of an oral carbohydrate-protein gel improves cycling endurance and prevents postexercise muscle damage. J Strength Cond Res. 2007;21(3):678–84.
77. Burke LM, Wood C, Pyne DB, Telford DR, Saunders PU. Effect of carbohydrate intake on half-marathon performance of well-trained runners. Int J Sport Nutr Exerc Metab. 2005;15(6):573–89.
78. Currell K, Jeukendrup AE. Superior endurance performance with ingestion of multiple transportable carbohydrates. Med Sci Sports Exerc. 2008;40(2): 275–81.
79. Currell K, Urch J, Cerri E, Jentjens RLP, Blannin AK, Jeukendrup AE. Plasma deuterium oxide accumulation following ingestion of different carbohydrate beverages. Appl Physiol Nutr Metab. 2008; 33(6):1067–72.
80. Triplett D, Doyle JA, Rupp JC, Benardot D. An isocaloric glucose-fructose beverage's effect on simulated 100-km cycling performance compared with a glucose-only beverage. Int J Sport Nutr Exer Metab. 2010;20(2):122–31.
81. De Hon O, Coumans B. The continuing story of nutritional supplements and doping infractions. Br J Sports Med. 2007;41:800–5.
82. Maughan RJ. Contamination of dietary supplements and positive drug tests in sport. J Sports Sci. 2005;23:883–9.