Nutrition Considerations in Special Environments for Aquatic Sports

Trent Stellingwerff, David B. Pyne, and Louise M. Burke

Elite athletes who compete in aquatic sports face the constant challenge of arduous training and competition schedules in difficult and changing environmental conditions. The huge range of water temperatures to which swimmers and other aquatic athletes are often exposed (16–31 °C for open-water swimming), coupled with altered aquatic thermoregulatory responses as compared with terrestrial athletes, can challenge the health, safety, and performance of these athletes. Other environmental concerns include air and water pollution, altitude, and jetlag and travel fatigue. However, these challenging environments provide the potential for several nutritional interventions that can mitigate the negative effects and enhance adaptation and performance. These interventions include providing adequate hydration and carbohydrate and iron intake while at altitude; optimizing body composition and fluid and carbohydrate intake when training or competing in varying water temperatures; and maximizing fluid and food hygiene when traveling. There is also emerging information on nutritional interventions to manage jetlag and travel fatigue, such as the timing of food intake and the strategic use of caffeine or melatonin. Aquatic athletes often undertake their major global competitions where accommodations feature cafeteria-style buffet eating. These environments can often lead to inappropriate choices in the type and quantity of food intake, which is of particular concern to divers and synchronized swimmers who compete in physique-specific sports, as well as swimmers who have a vastly reduced energy expenditure during their taper. Taken together, planned nutrition and hydration interventions can have a favorable impact on aquatic athletes facing varying environmental challenges.

Keywords: swimming, environment, nutrition

Athletes in modern elite aquatic sports, which include swimming, diving, synchronized swimming, and water polo, can face arduous training and competition schedules in difficult and changing environmental conditions. For example, depending on the event, age, and season, the elite swimmer may have between 30 and 100 races per year, crossing multiple time zones in varying countries, all with differing environmental, cultural, food, and fluid choices. Similar types of travel and competition demands are also placed on other aquatic athletes. They may also incorporate specialized programs involving adaptation to altitude, either by traveling to locations at high altitude or sleeping in simulated hypoxic conditions in nitrogen houses or tents. During peak competition phases, all aquatic athletes generally have accommodations that feature all-you-can-eat buffets, which challenge dietary restraint, especially in the more physique-dependent disciplines of synchronized swimming and diving.

The variability in water temperature can also be a significant environmental and physiological hurdle. The official rules of the international governing body for swimming, the Fédération Internationale de Natation (FINA), state that during competition temperatures must be between 25 and 28 °C for pool water and 16 and 31 °C for open-water swimming (OWS) for the 10-km Olympic marathon and the 5-, 10-, or 25-km races at the FINA World Championships (Shaw et al., 2014). In training, elite aquatic athletes can cover between 10 and 100 km/week\(^{-1}\) (10 and 35 hr/week\(^{-1}\)) in pool and OWS in which temperatures are not necessarily regulated. Furthermore, many swimmers undertake periodic altitude training or OWS in potentially polluted air and water. Together, these environmental challenges can add significant undesired and potentially detrimental stress that may compromise energy balance, recovery, immune function, optimal training adaptation, and ultimately performance. However, several nutritional interventions may help to mitigate the negative environmental effects and enhance adaptation and performance. Given the large diversity of needs and interests across varying aquatic sport disciplines, it is impossible to cover all areas in adequate detail. Therefore, we focus on the specific issues, and subsequent nutrition recommendations, faced by swimmers who are exposed to altitude training, varying water temperatures, and...
air and water pollution. The challenges of global travel and living in competition villages shared by all aquatic athletes are also addressed.

**Unique Physiological Responses Associated With Varying Swimming Environments**

An appreciation of the unique and specific physiological responses associated with swimming sets the stage for understanding how varying environmental conditions, and associated nutritional interventions, may affect aquatic athletes. Swimming training can place significant stress on various physiological systems and is distinctive in that it is the only sport conducted entirely in a body weight–supported prone or supine position in water, featuring simultaneous use of arms and legs for propulsion with low eccentric and central nervous system demands (Pyne & Sharp, 2014).

In terms of cardiodynamics, despite the prolonged hours of training, most elite swimmers actually demonstrate typical hemoglobin mass and blood plasma volumes that are similar to those of recreational to national-class endurance athletes (Heinicke et al., 2001; Wachsmuth et al., 2013). This outcome may relate to the water-based training environment of swimmers, in which the normal increase in aldosterone and antidiuretic hormone (or vasopressin) secretion and decreased glomerular filtration rate and urine volume typically found during endurance training are reduced (and possibly even abolished) during training in the water (Böning et al., 1988). Whether this adaptation is due to water itself or to the prone and supine training position of swimmers remains to be determined. Nevertheless, both body positions reduce venous pooling of blood in the legs, shifting blood to the thorax via increased central venous pressure and triggering increased diastolic ventricle filling, higher cardiac stroke volumes, and increased diuresis (Böning et al., 1988; Echt et al., 1974). Accordingly, compared with terrestrial athletes, swimmers need lower total blood volume to fill the active circulation during exercise (Boning et al., 1988; Echt et al., 1974). Thus, plasma and red cell volume-induced training adaptations appear to be attenuated by swim training as compared with upright terrestrial endurance training (Heinicke et al., 2001; Wachsmuth et al., 2013), which potentially affects training and nutrition recommendations in altered environments.

These cardiodynamic phenomena unique to swimming also play a role in altered thermoregulatory responses in water-based exercise compared with land-based exercise. Body temperature regulation on land occurs primarily via sweat evaporation. In contrast, both convection and conduction are the two primary ways to transfer heat in the water because evaporation does not occur during exercise in water (Nielsen & Davies, 1976). Thermal conductivity is approximately 25 times greater in the water than in the air, so water even marginally colder than body temperature is a significant heat sink and has the potential to cause hypothermia. Given that the normal human body temperature is about 37 °C, even swimming in 21 °C (~16 °C differential or heat sink) for a prolonged time can cause hypothermia (Brannigan et al., 2009; Castro et al., 2009). Conversely, 20 min of swimming at approximately 50% VO_{2}max in 34 °C water (still a ~3 °C heat sink) yielded an esophageal temperature increase of only 1 °C, whereas 20 min of running at approximately 50% VO_{2}max at a much cooler temperature (21 °C) drove esophageal temperature to 39 °C (Holmér & Bergh, 1974). It has long been known that there are greater VO_{2} demands when swimming in cold water (McArdle et al., 1976), which is thought to relate to decreased mechanical efficiency secondary to increased shivering thermogenesis. This study also demonstrated that decreased heart rates in cold-water swimming were entirely compensated for by an increased cardiac stroke volume (McArdle et al., 1976), possibly the result of increased peripheral and cutaneous vasoconstriction causing an even greater increase in central blood volume and venous return. Taken together, not only do swimmers have a completely different mechanism for heat dissipation than terrestrial athletes, many complex factors also affect individual temperature regulation, including water temperature, prone position while swimming, physique of the athlete, length and intensity of the swimming, acclimatization, and individual responses (Brannigan et al., 2009; Castro et al., 2009; Gerrard, 1999; Holmér & Bergh, 1974; Macaluso et al., 2013; McArdle et al., 1976).

In summary, given the substantial amount of time that swimmers train in water in a prone or supine position, coupled with alternative heat dissipation mechanisms and altered hematological adaptive responses, some of the conventional physiological responses with upright training in varying environments may not directly apply to aquatic sports (Boning et al., 1988; Brannigan et al., 2009; Echt et al., 1974; Gerrard, 1999; Heinicke et al., 2001; Wachsmuth et al., 2013). The physiological and adaptive responses to altered environments and associated nutrition interventions in swimmers clearly warrant further research attention.

**Altitude Training in Swimmers**

Altitude training is increasingly being used to prepare primarily swimmers for international competitions. Although use of altitude training has been explored for almost 40 years, there have been few controlled, or even observational, experimental altitude studies on top-level swimmers (Wilber, 2007). Given the different demands of the other aquatic disciplines, there has been little research or interest in altitude training for synchronized swimming, diving, and water polo. In more recent years, a number of options for simulating altitude for training and exposure have been developed, such as altitude chambers or houses, tents, or rebreathing apparatuses. The benefits of altitude training are typically small and variable and depend on the level and duration of hypoxic stimulus and
underlying health and fitness of the athlete (Bonetti & Hopkins, 2009). Our focus here is on real or classical altitude training and how nutritional requirements might vary in comparison with near sea-level training. We should highlight that nearly all altitude nutrition and hydration studies have been conducted at more extreme altitudes (>3,500 m), whereas most altitude-based swimming pools are located at moderate altitudes (approximately 2,000–2,500 m), and most FINA competitions are conducted in major cities near sea level.

Understanding nutritional requirements at altitude requires knowledge of the physiological changes associated with training and exposure. It is understood that some athletes exhibit losses in both lean mass and fat mass when undertaking altitude training, particularly at very high altitudes. Altitudes higher than 3,500 m can cause a 10%–17% increase in basal metabolic rate (Butterfield, 1999), appetite suppression (Kayser, 1992), shifts toward increased carbohydrate utilization (Brooks et al., 1991), and ultimately weight loss (Butterfield et al., 1992; Kayser, 1992). All these effects can be mitigated through adequate carbohydrate and energy intake (Butterfield et al., 1992; Kayser, 1992). Studies of energetic requirements, caloric intake, and changes in body composition at moderate altitudes are lacking, but some swimmers might be at risk for modest energy deficiency, particularly if training loads are high. Therefore, daily monitoring of body mass when training or competing in challenging environments may be informative for swimmers, coaches, and support staff.

Both erythropoietic and nonerythropoietic mechanisms of adaptation to altitude training appear to be involved (Gore et al., 2007); however, studies on physiology and performance have produced mixed results. A key requirement facilitating adaptive processes at altitude is underlying iron status; thus, iron status should be screened before altitude training. Erythropoetin is a glycoprotein hormone responsible for production and release of reticulocytes from bone marrow that drives an increase in red cell mass (hemoglobin), blood volume, and oxygen-carrying capacity. Iron is an integral part of the hemoglobin molecule, and athletes with low iron may have a compromised ability to produce erythrocytes. Current guidelines indicate that athletes going to altitude should increase their dietary intake of iron, or undertake iron supplementation with advice from qualified support staff, when prealtitude serum ferritin concentrations are less than 30 μg/L\(^{-1}\) for females or less than 40 μg/L\(^{-1}\) for males (Bergeron et al., 2012).

Several other nutritional interventions should be considered for maintaining immune function and antioxidant capacity during altitude training. Altitude training and exposure can induce mild to moderate fluctuations in underlying immune parameters such as salivary immunoglobulin A (Mazzeo, 2005) and cytokine and lymphocyte proliferative responses (D.V. Pyne et al., 2000). The nutritional countermeasures for the immune system center on augmented carbohydrate and antioxidant consumption and possibly plant polyphenols and probiotics (Gleeson, 2013). Emphasizing antioxidant dietary sources may be important because antioxidant buffering capacity in highly trained runners may not be sufficient to counterbalance free radical overproduction generated by acute hypoxic exposure with or without exercise or training (Pialoux et al., 2009). In this study, mild exercise at high altitude (3,000 m) elicited a substantial elevation in free radicals and a reduction in antioxidant capacity. However, whether increased antioxidant intakes at altitude would sustain or restore immune function or increased or attenuated training adaptations remains to be elucidated. Although requiring more scientific validation, given that several sea-level studies have demonstrated attenuated endurance training adaptations with pure single-source high-dose antioxidant supplementation (e.g., >1 g/day\(^{-1}\) of pure vitamin C; Gomez-Cabrera et al., 2008), dietary recommendations should include greater emphasis on food sources of antioxidants rather than supplements alone.

Altitude training also results in increased demand for fluids. The mountain conditions of most altitude venues are characterized by cold and dry air that can increase loss of respiratory water (Wilber, 2007). Altitude-induced diuresis and impaired thirst are typical responses in the initial hours of altitude exposure. Increased rates of ventilation and dry (low-humidity) air can exacerbate loss of water from the respiratory system. Collectively, the total water losses from the urinary and respiratory systems could be as high as 2 L/day\(^{-1}\), which needs to be made up via increased hydration. Consequently, fluid intakes of as much as 4–5 L/day\(^{-1}\) have been recommended (Wilber, 2007) for athletes training and competing at altitude in a variety of sports. Monitoring of fluid intakes, urine-specific gravity, and body mass changes is useful in identifying swimmers at risk for dehydration during altitude training and exposure.

**Thermoregulatory Responses in Swimmers in Varying Water Temperatures**

The wide range of water temperatures encountered by swimmers in training and OWS competition is the primary influence on deviations in core body temperature (Branigan et al., 2009; Castro et al., 2009). Thus, it is important to recognize that the FINA OWS World Championship features race distances of 5 k, 10 k, and 25 k, which take elite athletes approximately 1 hr, 2 hr, and 5.5–6 hr, respectively.

Although the unfortunate death of American OWS athlete Fran Crippen in October 2011 highlighted the potential health dangers of prolonged warm-water swimming, hypothermia is still the most prevalent medical risk associated with OWS during long-distance events (Gerrard, 1999). Several recent OWS studies of 10- to 19.2-km races, both conducted at a water temperature of approximately 21 °C, had hypothermia incidence rates of about 21%–83% (Branigan et al., 2009; Castro et
al., 2009). However, there is much controversy as to the most medically relevant criteria, thermometer type, and measurement location to accurately classify hypothermia. Probably the most important intervention to prevent, or attenuate, OWS hypothermic responses appears to be an athlete’s inherent body fat, which can be chronically manipulated by a combination of energy intake and expenditure in a race-targeted periodized fashion. Indeed, depending on the aquatic event, compared with weight-supported terrestrial sports, extra body fat is of less consequence to overall swimming performance and may be of value in cold-water OWS conditions for both buoyancy and protection against hypothermia (Brannigan et al., 2009; Gullstrand, 2000; Holmér et al., 1974; Macaluso et al., 2013; Shaw et al., 2014). Nevertheless, it is important to recognize that a higher fat physique may limit an athlete’s ability to dissipate heat, and place the athlete at higher risk for heat stress or heat stroke, in warm-water conditions (Macaluso et al., 2013). Elite open-water swimmers undertake different events in varying water temperatures around the world, so periodizing body fat to the targeted event water temperature may not be practically feasible given the frequency of competitions. Finally, athletes should always be screened for preexisting viral illness because some evidence has suggested that this may predispose individuals to further heat stress and put them at a higher risk of developing a serious cardiomyopathy, especially in warm to hot conditions (Casa et al., 2012; Kindermann et al., 2012).

Very few studies have examined nutrition interventions in swimmers to moderate the physiological effects of varying water temperatures, but extension of findings from terrestrial exercise has provided some insights. First, optimal prerace fueling (glycogen stores) and in-race carbohydrate and fluid intake appear to combat shivering thermogenesis and the preferential glycogen utilization when cold (for a review, see Haman, 2006). Thus, optimizing in-race OWS fueling should be a priority (Shaw et al., 2014). A plethora of studies have also demonstrated positive effects of cold water or slushy consumption on attenuating OWS hypothermic responses appears to be an athlete’s inherent body fat, which can be chronically manipulated by a combination of energy intake and expenditure in a race-targeted periodized fashion. Indeed, depending on the aquatic event, compared with weight-supported terrestrial sports, extra body fat is of less consequence to overall swimming performance and may be of value in cold-water OWS conditions for both buoyancy and protection against hypothermia (Brannigan et al., 2009; Gullstrand, 2000; Holmér et al., 1974; Macaluso et al., 2013; Shaw et al., 2014). Nevertheless, it is important to recognize that a higher fat physique may limit an athlete’s ability to dissipate heat, and place the athlete at higher risk for heat stress or heat stroke, in warm-water conditions (Macaluso et al., 2013). Elite open-water swimmers undertake different events in varying water temperatures around the world, so periodizing body fat to the targeted event water temperature may not be practically feasible given the frequency of competitions. Finally, athletes should always be screened for preexisting viral illness because some evidence has suggested that this may predispose individuals to further heat stress and put them at a higher risk of developing a serious cardiomyopathy, especially in warm to hot conditions (Casa et al., 2012; Kindermann et al., 2012).

Some evidence has suggested that an individual athlete can partially physiologically adapt to cold water (Vybiral et al., 2000). Conversely, heat acclimation adaptations do not seem to occur as readily in swimmers as in upright land-based athletes (D.F. Gerrard, unpublished observations), possibly because of the altered cardiodynamics in swimmers. For terrestrial athletes, plasma volume expansion is a typical acute adaptation (5–7 days) demonstrated with upright heat acclimation training (Garrett et al., 2011), which is further augmented through optimal protein and carbohydrate intake during recovery (Goto et al., 2010). However, this plasma volume response appears to be negated when exercising and recovering in the supine position (Nagashima et al., 2000). Furthermore, terrestrial heat acclimation also causes an increased sweat rate, which does not offer any thermoregulatory benefit to swimmers and could potentially be detrimental to open-water swimmers via accelerated dehydration. Obviously, much more research is needed to target the unique physiological responses of swimmers in varying water temperatures, coupled with nutritional interventions known to enhance adaptation and performance outcomes in terrestrial athletes.

### Air and Water Pollution

There is a paucity of research on the impact of air pollution on athlete health and performance (Cutrufello et al., 2012; Rundell, 2012), let alone the impact that nutrition may have in neutralizing these deleterious effects in swimmers. A higher prevalence of air hyperresponsiveness is evident in athletes who train and compete in environmental conditions of cold dry air or when air pollution reaches high levels (Rundell & Sue-Chu, 2013). The primary preventive strategy is avoidance by having athletes train indoors away from outdoor venues at higher risk of air pollution. In aquatic sports, some athletes experience intermittent respiratory issues related to chlorination of pool water and poor air quality (Bougault & Boulet, 2012, 2013). Accordingly, as many as 74% of elite swimmers report nasal obstruction, rhinorrhea, sneezing, and nasal itching throughout a training season, consistent with reports of as many as 76% of swimmers having symptomatic or asymptomatic airway hyperresponsiveness, exercise-induced bronchoconstriction, or both (Bougault & Boulet, 2012). The causes of these high rates of respiratory issues in elite swimmers are not entirely clear but may relate to low breathing frequency or high and forceful breathing or tidal volumes that favor increased respiratory penetration of volatile chlorinated products right at the pool surface (Bougault & Boulet, 2012). Athletes with asthma may benefit from antioxidant therapy that has yielded beneficial clinical outcomes in nonathletic patients (Wood et al., 2012). Increasing the dietary intake of carotenoids (antioxidants) improved clinical asthma outcomes, but only after increased fruit and vegetable intake, suggesting that whole-food interventions are most effective. Similar
to immune stress at altitude, aquatic athletes dealing with air and water pollution may also potentially benefit from nutritional interventions such as adequate carbohydrate and antioxidant intake and possibly plant polyphenols and probiotics (Gleeson, 2013). However, in both instances more information in elite athletes, and aquatic athletes, is required to make definitive recommendations.

FINA OWS rules (4.6) state that each OWS course local organizing committee must provide a certificate of suitability (water purity and swimmer safety) for the use of the venue, issued by the appropriate local health and safety authorities within 72 hr of race day. However, beyond engaging the local health authority to assess water purity according to globally varying local standards, there are no specific or internationally standardized recommendations for water pollution standards for OWS events. Given that swimmers naturally ingest some water, especially in OWS in which athletes are in close proximity in a dynamic environment (e.g., swells and waves), more research is required to assess the prevalence and treatment of immune dysfunction, sickness, and gastrointestinal distress and related short- and long-term health and performance outcomes. Practical recommendations to minimize adverse effects of water pollution during OWS include choosing clean-water venues for all training to minimize total pollution exposure and rehearsing feed-zone practices to limit inadvertent consumption of polluted water.

**Travel Nutrition, Jet Lag, and Travel Fatigue**

With the ever-increasing globalization of aquatic sports, modern athletes are constantly traveling to training camps and competitions, resulting in travel fatigue, jet lag, and new environmental stressors associated with their destination (e.g., altitude, food and fluid quality issues, cultural differences). For nearly all aquatic athletes, the major targeted global competitions (e.g., Olympic Games or FINA World Championships) will involve travel to a location that is both distant and foreign to the athlete’s home base and culture. Travel fatigue is defined as negative physiological, psychological, and environmental factors that accrue during a single trip and that can accumulate throughout an entire season, resulting in reduced recovery and athletic performance (Samuels, 2012). Travel fatigue can be independent of and dependent on jet lag. Conversely, jet lag is a syndrome of symptoms manifested exclusively due to the time-phase shift to a new time zone (Reilly et al., 2005, 2007; Samuels, 2012). Addressing travel challenges requires special considerations for both the trip itself and the issues faced in the new environment.

Three major themes for nutrition during travel involve the adjustment of the body clock during and after transit, alteration of travel nutritional needs, and change in food availability because of cultural changes at the new training camp or competition location. Table 1 provides a summary of important issues and some practical suggestions for how they should be addressed.

At the base of the hypothalamus are the suprachiasmatic nuclei cells, which are the site of the human body clock. Reilly et al. (2005, 2007) provided a complete biological review of the body clock, but in short the suprachiasmatic nuclei are closely linked to the pineal gland, which secretes endogenous melatonin. Suprachiasmatic nuclei are in circadian rhythm, and for an individual’s body clock to optimally synchronize to his or her environment, adjustments are made by zeitgebers, which are defined as any external or environmental cues that entrain, or synchronize, one’s biological rhythms to the Earth’s 24-hr light–dark cycle. Natural daylight and darkness provide the most dominate zeitgebers for body clock readjustment, and endogenous melatonin release is intimately linked to light–dark cycles. Accordingly, one of the best ways to start to reset the body clock and overcome jet lag is the timely exposure of light and dark starting immediately on travel, according to the new time zone (Reilly et al., 2005, 2007; Samuels, 2012). The voluntary eating and drinking pattern is also relevant to circadian readjustment, with recommendations to eat and drink as normally as possible immediately on commencing travel to the new time zone (Reilly et al., 2007). Taken together, the physiological circadian rhythm is optimally readjusted by both endogenous (e.g., clock driven, such as endogenous melatonin release) and exogenous (voluntary environmental components such as the timing of light and eating) factors, which are going to play the most dominant role in mitigating jet lag symptoms. Although more research is required to establish efficacy, several other potential supplement and nutrition-based interventions may assist in establishing a new circadian rhythm when jet lagged, including the strategic timing of caffeine (morning or early day of new time zone), melatonin (evening of new time zone), high-glycemic-index carbohydrate meals and tryptophan-containing foods before sleeping (Reilly et al., 2007; Samuels, 2012).

Although the effects are highly individual, some athletes use exogenous melatonin supplementation (N-acetyl-5-methoxytryptamine) to assist with sleep onset when dealing with jet lag (Hermheimer & Petrie, 2002); general recommendations suggest 3–5 mg of melatonin taken 30 min before the new time-zone bedtime (Hermheimer & Petrie, 2002; Samuels, 2012). When used appropriately, a meta-analysis has indicated that melatonin decreases sleep onset by an average of 7 min and is well tolerated with little evidence of adverse effects or hang-over symptoms (Buscemi et al., 2006). However, whether a 7-min decrease is beneficial for recovery or performance remains to be seen. Furthermore, the purity of any supplement can never be guaranteed, and the individual and long-term effects are always unknown; thus, some caution is warranted.

Travel generally imposes several acute changes in the athlete’s nutritional needs. First is the decrease in energy requirements that accompanies the forced reduction in activity patterns while the athlete is in transit. In the case of long-haul travel, especially for high training-volume athletes, the trip will incur a dramatic reduction in energy expenditure over several days. This may be
### Table 1 Challenges and Solutions for the Traveling Athlete

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<thead>
<tr>
<th>Challenges of Traveling</th>
<th>Strategies to Cope with the Challenges of Traveling</th>
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<tbody>
<tr>
<td>• Disruptions to the normal training routine and lifestyle while the athlete is en route</td>
<td>1. Planning ahead</td>
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<td>• Changes in climate and environment that create different nutritional needs (which are especially the case during training camps at altitude or for heat acclimatization)</td>
<td>• The athlete should investigate food issues on travel routes (e.g., airlines) and at the destination before leaving home. Caterers and food organizers should be contacted well ahead of the trip to let them know meal timing and menu needs.</td>
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<td>• Jet lag</td>
<td>2. Supplies to supplement the local fare</td>
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<td>• Changes to food availability, including absence of important and familiar foods</td>
<td>• A supply of portable and nonperishable foods should be taken or sent to the destination to replace important items that may be missing.</td>
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<td>• Reliance on hotels, restaurants, and takeaways instead of home cooking</td>
<td>X Suitable items include breakfast cereal and cereal bars, powdered milk and liquid meals, dried fruit and nuts, sports drinks and protein powders, juice concentrates, and freeze-dried and canned meals.</td>
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<td>• Exposure to new foods and eating cultures</td>
<td>X The athlete should consider what is available in the new location versus the weight and convenience of traveling with extra food.</td>
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<td>• Temptations of an all-you-can-eat dining hall in an athletes’ village</td>
<td>X The athlete should also check with the local countries’ customs and quarantine to see what foods are permitted to be brought into the country of travel.</td>
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<td>• Risk of gastrointestinal illnesses as a result of exposure to food and water with poor hygiene standards</td>
<td>• The athlete should be aware that many catering plans only cover meals. Because the athlete’s nutrition goals are likely to include well-timed and well-chosen snacks, supplies should be taken to supplement meals en route and at the destination.</td>
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<td>• Excitement and distraction of a new environment</td>
<td>3. Eating and drinking well en route</td>
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<td>• Many athletes will turn to boredom eating when confined. Instead, they should eat according to their real needs, taking into account the forced rest while traveling.</td>
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<td>• When moving to a new time zone, the athlete should adopt eating patterns that suit his or her destination as soon as the trip starts. This will help the body clock to adapt.</td>
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<td>• Unseen fluid losses in air-conditioned vehicles and pressurized plane cabins should be recognized, and a drinking plan should be organized to keep the athlete well hydrated.</td>
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<td>X Fluid choices should be appropriate to the athlete’s energy requirements.</td>
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<td>X Caffeinated drinks have minimal negative effect on hydration and may even supply a substantial amount of fluid to the diets of habitual consumers of tea or coffee. However the intake of caffeine should be considered in view of sleep patterns.</td>
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<td>4. Taking care with food and water hygiene</td>
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<td>• It is important to find out whether the local water supply is safe to drink. Otherwise, the athlete should stick to drinks from sealed bottles or hot drinks made from well-boiled water. Ice added to drinks is often made from tap water and may be a problem.</td>
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<td>• In high-risk environments, the athlete should eat only at good hotels or well-known restaurants. Food from local stalls and markets should be avoided, however tempting it is to have an authentic cultural experience.</td>
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<td>• Food that has been well cooked is the safest; it is best to avoid salads or unpeeled fruit that has been in contact with local water or soil.</td>
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<td>5. Adhering to a food plan</td>
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<td>• The athlete should choose the best of the local cuisine to meet his or her nutritional needs, supplementing with his or her own supplies when needed</td>
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<td>• The athlete should be aware that training and race or event schedule may overlap with meal times, especially in countries with a different culture of eating patterns or in locations in which catering options are inflexible. They may need to request special consideration, including boxed meals or snacks that can be kept or taken to the event venue.</td>
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<td>• The athlete should be assertive in asking for what he or she needs at catering outlets—e.g., low-fat cooking styles or an extra carbohydrate choice.</td>
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<td>• The challenges of all-you-can-eat dining should be recognized. The athlete should resist the temptation to eat what is there or what everyone else is eating in favor of his or her own meal plan.</td>
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*Note.* From Burke (2008).
further disrupted by poor eating practices associated with
the boredom of travel or exposure to inappropriate
energy-dense foods (e.g., reliance on fast foods)
coupled with the reduced training volumes during the
initial phases of overcoming jet lag. Conversely, athletes
who continue to have high energy requirements may
find themselves with inadequate access to food while
traveling. Although these experiences may not seem
significant in the athlete’s overall nutrition program, if
such travel is undertaken regularly, just before important
events, or both, it may interfere with good management
of physique and performance goals. Therefore, athletes
and management are advised to construct an eating plan
for travel that incorporates the best use of airline catering,
en-route restaurants, and opportunities to take personal
food supplies.

The impact of long-haul flight on hydration status
is equivocal (Landgraf et al., 1994; Schobersberger et
al., 2002; Schumacher et al., 2012) and will depend
on pretravel hydration status, length of flight, amount
of in-flight fluid consumption, and cabin humidity and
temperature. However, given the low humidity in airline
cabins, fluid intake should be emphasized to ensure
optimal whole-body hydration levels on arrival. Potential
travel dehydration is compounded by a lack of, or change
in, access to fluids and usual drinking practices. Some
athletes, particularly those with spinal cord injury, deliber-
ately limit fluid intake during long-haul travel to avoid
the disturbance to sleep caused by a need for frequent
urination. Although the athlete will have reduced fluid
requirements during the trip itself, even mild dehydration
may exacerbate travel fatigue and jet lag. During travel,
generic advice is to avoid the intake of caffeinated drinks
(e.g., coffee or cola) because of the potential disturbance
to hydration attributed to caffeine intake. However,
despite common beliefs, the intake of small to moderate
amounts of caffeine has a negligible effect on diuresis
or the hydration status of habitual caffeine consumers
(Armstrong, 2002). Therefore, athletes who habitually
consume caffeinated drinks may actually reduce their
fluid intake and fluid balance if they are forced to avoid
these drinks in favor of fluids that are perceived as less
enjoyable. Heavily caffeinated drinks should continue to
be avoided because of their effects on diuresis, sleep, or
caloric contribution to the athlete’s overall nutrition plan
rather than their effects on urinary output. The exac-
eration of the deleterious intoxicating effects of alcohol
on recovery, hydration, and health during aircraft travel
should also be taken into account.

The athlete may also face a variety of new environ-
mental (e.g., climate and altitude), cultural, and practical
challenges in meeting his or her nutritional needs once he
or she has arrived at the destination. A foreign location,
language differences, food allergies and intolerances,
and travel experience (athlete age), combined with an
unaccustomed and unknown food supply, may result in
inappropriate food choices. Athletes may find themselves
without the foods that underpin their nutritional, social,
and enjoyment practices. Even travel to a familiar location
will still expose athletes to different food and catering
situations with altered access to routine food and food
preparation. A substantial part of an athlete’s new food
intake may come from hotels and restaurants rather than
being tailored to individual athlete needs. Even when the
general catering has been organized according to sports
nutrition principles, it may not meet the meal timing
and individual needs of athletes, such as food allergies
or intolerances or religious practices (Cummings, 2010).
Many times, meal timing needs to be established
around pool availability dictating training times, espe-
cially with the limited number of pools at altitude. Cater-
ing must meet a variety of food preferences, including
cultural and religious diversity, dietary restrictions,
event-specific sports nutrition needs, and changes in
nutrition needs between periods of final training, taper,
competition, and celebration (Meyer et al., 2013; Pelly et
al., 2011). Generally there is much more free time during
the taper and competition period, which can result in
unnecessary eating as part of entertainment activities or
to fill time. This is especially true for cafeteria or buff-
ety-style eating, which is the standard or preferred catering
arrangement in most major global championships (Cum-
nings, 2010).

In some cases, the altered access to food leans in
the direction of too much rather than not enough. Many
athletes, especially young and inexperienced athletes, find
it difficult to maintain habitual or desired eating patterns
with buffet-style eating because it provides different
environmental cues than a conventional food environ-
ment. Challenges include the opportunity to overeat when
offered a large variety of foods in relatively unlimited
amounts and the absence of the normal supervision or
constraints to food intake (e.g., cost, availability). Social
science research has indicated that food choice and intake
are heavily influenced by many unappreciated external
factors underpinning the ambience of an eating occasion,
such as the environment (lighting, mood, and tempera-
ture), number of eating partners, and the presentation of
food (Stroebele & De Castro, 2004). Furthermore, ad
libitum energy intake is not immediately matched by
reduced energy expenditure, as is found during the com-
petition phase (Stubbs et al., 2004). Education may help
athletes to be firmly aware of their individual nutritional
requirements and to learn behavioral strategies that will
allow them to achieve their goals regardless of the food
environment.

In many countries, the standards of hygiene, food
handling, and water sources may be suboptimal. Con-
sequently, traveling athletes and their support staff risk
exposure to gastrointestinal pathogens and debilitating
illness, exacerbated through poor personal hygiene. Poor
food hygiene, coupled with a possible depression of the
immune system associated with heavy training or psychol-
oggical pressures of high-stakes competition, can cause
a “perfect storm” for illness and infection. The impact
that nutrition can have on the immune system of aquatic
athletes is covered elsewhere (D. B. Pyne et al., 2014).
In summary, the experiences and opportunities afforded
athletes through international travel must be weighed against the challenges and managed to enable them to train and compete to their full potential.

Summary

Elite aquatic athletes are required to undertake arduous training and competition schedules in challenging conditions including varying water temperatures, air and water pollution, altitude, and jet lag or travel fatigue. Nutrition interventions that might mitigate the negative environmental effects include adequate hydration, carbohydrate, and iron intake while at altitude; manipulation of fluid and carbohydrate intake during races according to varying water temperatures; and careful food and fluid hygiene practices when traveling.

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References


