WORLD AQUATICS

NUTRITION FOR AQUATIC ATHLETES

A practical guide to eating for health and performance

Second Edition - 2023

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Key Messages

Many factors contribute to success in sport, including talent, training, motivation and resistance to injury and illness. When highly talented, motivated, and well-trained athletes gather for competition, the margin between victory and defeat is usually small. Attention to every detail can make that vital difference, and nutrition is a key element of the serious athlete's preparation.

Diet affects performance in all events, and the foods that we choose in training and competition will affect how well we train and compete. Athletes need to be aware of their nutritional goals and of how they can select an eating strategy to meet those goals.

Diet may have its biggest impact during training, and a good diet will help support consistent intensive training while reducing the risk of illness or injury. Good food choices can also optimise the adaptations in muscle and other tissues in response to the training stimulus.

Athletes are all different, and there is no single diet that meets the needs of all athletes at all times. Individual needs also change across the season and athletes must be flexible to accommodate this.

Getting the right amount of energy to stay healthy and to tolerate the often large training volumes is a key goal of the everyday diet. Consume too much energy and body fat increases: too little and performance falls and illness results. Developing the perfect physique requires careful integration of training and diet.

Carbohydrate is a key nutrient for energy supply, but carbohydrate needs will depend on the training load and therefore vary from day to day and across the season. Athletes must be aware of foods that are good sources of carbohydrate and make these a focus of their diet.

Protein foods are important for building and repairing muscles, but a varied diet containing everyday foods will generally supply more than enough protein. The timing and type of protein are as important as the amount of protein in the diet. Well-chosen vegetarian diets can meet an athlete's protein needs.

A varied and wholesome nutrient-rich diet that meets energy needs and is based largely on vegetables, fruits, beans, legumes, grains, lean animal meats, dairy produce and oils should ensure an adequate intake of all essential vitamins and minerals.

Maintaining hydration is important for performance. An adequate intake of fluid before, during (where appropriate), and after exercise is especially important in hot climates. Salt (sodium) replacement is important when sweat losses are high, but needs vary between athletes.

Athletes are cautioned against the indiscriminate use of dietary supplements, but careful and strategic use of a small number of supplements and sports foods, ideally in consultation with a sports nutrition expert, may benefit some athletes.

Food is an important part of life, and athletes should enjoy the foods that they eat, confident in the knowledge that they have made wise choices.

This booklet contains information that will help all athletes in aquatics sports to make informed choices to meet their nutritional needs in different situations. It is no substitute for individual advice from a qualified professional but tries to give practical information that will be of use to the serious athlete.

Nutrition for the Elite Athlete

Competitive athletes may train 300-600 times each year, but most will eat 1200-1600 times in the same period. Therefore, well-chosen eating practices have much to offer the athlete:

- Fuel to train and perform at a competitive level
- Optimum gains from the training program
- Enhanced recovery between workouts and between events
- Achievement and maintenance of an ideal body weight and physique
- Benefits from the many health-promoting components of food
- A reduced risk of injury, overtraining fatigue and illness
- Sustained concentration and mental skills over the day
- Confidence in being well-prepared to face competition
- Achievement of consistent high-level competition performances
- Enjoyment of food and social eating occasions at home and during travel

Despite these advantages, many athletes do not meet their nutrition goals. Common problems and challenges include:

- Poor knowledge of foods and inadequate cooking skills
- Poor or outdated knowledge of sports nutrition
- Lack of access to dietitians /nutrition professionals or other credible resources
- Inadequate finances
- Busy lifestyle leading to inadequate time to obtain or consume appropriate foods
- Poor availability of good food choices
- Frequent travel
- Indiscriminate use of large amounts of supplements or failure to use evidence-based supplements and sports foods in the appropriate way

The information in this booklet is designed to provide coaches and athletes with an overview of the latest guidelines in sports nutrition. While there is no such thing as a magic diet or food, there are many ways in which eating well can allow athletes at all levels of performance to achieve the specific goals of their training and competition programs.

It makes no sense to train hard and ignore the benefits that good food choices offer to maximise training and performance.

The information is based on a conference hosted by World Aquatics in London in December 2013.

This booklet is based on the scientific contributions to the conference of: Margo Mountjoy, Ron Maughan, Louise Burke, Dan Benardot, Dave Costill, Greg Cox, Wim Derave, Anu Koivisto, Anna Melin, Iñigo Mujika, David Pyne, Sherry Robertson, Rick Sharpe, Greg Shaw, Trent Stellingwerff, Kevin Tipton, Evert Verhagen, Wes Zimmermann, Cees-Rein van den Hoogenband, Saul Marks, David Gerrard, Kevin Boyd, and James Miller.

Part 1 General Principles: Nutrition Goals & Eating Strategies

Energy needs

An athlete's self-selected energy intake sets the *"budget"* from which an athlete must meet their needs for carbohydrate, protein and fat, as well as the range of foods that provide vitamins, minerals and other health-promoting dietary factors.

An athlete's energy requirements are made up of several components:

- baseline metabolic needs (such as the energy required to support cellular maintenance, temperature regulation and immune health),
- growth (including an increase in muscle mass) and,
- physical activity.

Energy expended in one of these processes is not available for others, so the diet must provide sufficient energy to meet the needs of all essential functions. Physical activity – or in the case of an athlete, the intensity, duration and frequency of training sessions and competitions - will play a strong role in determining daily energy requirements.

When daily intake of food energy from carbohydrate, fat, protein (and alcohol) is equal to energy expenditure, the athlete is said to be in *energy balance*.

Energy balance = Energy intake – energy expenditure

This means there is neither a net loss nor gain from the body's energy stores of fat, protein and carbohydrate, and is the desirable state for much of our lives. These energy stores play a number of important roles related to exercise performance, contributing to:

- an athlete's size and physique (e.g. body fat stores and muscle mass)
- function (e.g. muscle mass)
- fuel for exercise (e.g. muscle and liver glycogen stores)

Athletes often want to change their energy balance, either to produce an energy deficit (principally to reduce the size of body fat stores and therefore, body mass) or to achieve an energy surplus (principally to support growth or support the gain of muscle mass). This can be done either by altering energy intake, energy expenditure or both components.

However, an important new concept is that of *energy availability.* This is defined as the energy that is available to the body after the energy cost of physical activity has been deducted from daily energy intake. Energy availability is therefore, the amount of energy that can be expended to look after the body's physiological needs.

Energy availability = Energy intake – Energy cost of training/competition*
(= total energy expenditure during the exercise minus the background cost of being sedentary during this period)*

The body can cope with a small drop in energy availability, but if it becomes too great, this will compromise its ability to undertake the processes needed for optimum health and function, and ultimately, training.

We now recognise that many health problems commonly seen in athletes are associated with low energy availability - these include menstrual disturbances in female athletes, reduced basal metabolic rate, compromised immunity, poor hormonal function and impaired bone density. Importantly, there is mounting evidence, that low energy availability directly reduces performance. For example, a study of a swimming squad showed that swimmers whose diets were found to be energy deficient suffered a decrease in race speed after a lengthy training block while their teammates gained a substantial improvement in their swimming speed with the same workouts. Unfortunately, low energy availability may be not always be easily visible since it often occurs in athletes who are weight stable and not necessarily lean/light.

Although any reduction in energy availability has some effect on the body, researchers have identified a threshold below which the consequences are particularly harmful. This is usually discussed in terms of an athlete's Fat Free Mass (FFM) – i.e. Body mass minus Body fat. This threshold is set at 30 kcal (125 kJ) per kg FFM. Examples of adequate and low energy availability are provided below.

There are three situations that are typically associated with low energy availability.

- Disordered eating and eating disorders. We used to think this was the main cause of energy deficiencies, causing some stigma to the athletes involved. Disordered eating requires early intervention and specialist help, but we now know that many athletes can get into situations of low energy availability without this backdrop
- Restricted eating for weight control or loss or body fat. Many athletes undertake such campaigns with the best of intentions and, often, good reasons. However, the degree of energy deficit achieved by reduced energy intake or increased exercise may be too severe for good health or to support training. Even when weight loss is undertaken without any problem behaviour or undue stress, trying to achieve it at too fast a rate is likely to lead to unnecessary compromises of health and performance. In some cases, low energy availability causes such a reduction in metabolic rate that the athlete's energy needs drop to the point that they no longer lose weight on an energy restricted diet
- Inadvertent failure to increase energy intake sufficiently during periods of training or competition that are high in volume and/or intensity. Some athletes undertake extremely strenuous training or competition programs. Appetite, time for preparing and eating food, and awareness of intake are just some of the factors influencing our food intake that

may not always keep pace, especially when there is a sudden increase in exercise load. The practicality of eating a high energy intake day after day can be challenging for many athletes. Some may be unaware that they are falling behind in meeting their energy needs, or that it is problematic

Tips for maintaining adequate energy availability

- ✓ Be aware of energy needs and how these might vary over time. Be prepared to scale energy intake up and down according to the changing energy costs of daily training or competition. Be aware also of additional needs for growth. Ideas for achieving a high energy intake are found in the next section
- ✓ Take care when there is a change in your food environment – particularly when travelling or when changing your home situation. It can take time and a conscious effort to re-establish new eating patterns when opportunities to eat or access to suitable foods are altered
- ✓ Do not embark on drastic diets that limit energy intake or food variety. Even when loss of weight or body fat is likely to achieve better health and performance, severe energy restriction is associated with unnecessary consequences of low energy availability. Where possible, plan weight loss programs so that they can be undertaken at a slower and less harmful pace
- ✓ If you are developing stress related to food and body image, seek expert help at an early stage
- ✓ Female athletes should treat an interruption to a normal menstrual cycle as a problem that also needs early assessment and intervention
- ✓ If you are unsure about your energy needs and how to achieve them, consult a sports nutrition expert
- ✓ Note that the consequences of low energy availability include irreversible loss of bone, as well as impairment of hormone, immune and metabolic function. It's not worth it!

Examples of different levels of energy availability

1. High energy availability for growth or gain of body mass

Energy availability	Example	
> 45 kcal	Athlete A:	65 kg and 20% body fat
(> 189 kJ)	FFM =	80% x 65 kg = 52 kg
per kg Fat Free Mass	Weekly training =	5600 kcal (23.5 MJ)
(FFM)	Daily energy intake =	3520 kcal (14.7 MJ)
	Energy availability =	(3520-800)/52
		= 52 kcal/kg FFM (219 kJ)

2. Adequate energy availability for weight maintenance

Energy availability	Example	
~ 45 kcal	Athlete B:	65 kg and 15% body fat
(~ 189 kJ)	FFM =	85% x 65 kg = 55 kg
per kg Fat Free Mass	Weekly training =	5600 kcal (23.5 MJ)
(FFM)	Daily energy intake =	3285 kcal (13.8 MJ)
	Energy availability =	(3285-800)/55
		= 45 kcal/kg FFM (189 kJ)

3. Reduced energy availability but still adequate for healthy weight loss (or weight maintenance at reduced metabolic rate

Energy availability	Example	
30-45 kcal	Athlete C:	55 kg and 20% body fat
(125-189 kJ)	FFM =	80% x 55 kg = 44 kg
per kg Fat Free Mass	Weekly training =	5600 kcal (23.5 MJ)
(FFM)	Daily energy intake =	2340 kcal (9.8 MJ)
	Energy availability =	(2340-800)/44
		= 35 kcal/kg FFM (164 kJ)

4. Low energy availability – health implications

Energy availability	Example	
< 30 kcal	Athlete D:	55 kg and 25% body fat
(< 125 kJ)	FFM =	75% x 55 kg = 41 kg
per kg Fat Free Mass	Weekly training =	5600 kcal (2.35 MJ)
(FFM)	Daily energy intake =	1980 kcal (8.3 MJ)
	Energy availability =	(1980-800)/41
		= 29 kcal/kg FFM (120 kJ)

Carbohydrates
For training and recovery

Carbohydrate provides an important fuel source for the brain and muscle during exercise. A long history of studies shows that the performance of sports involving prolonged activity, high intensity efforts, skill and concentration, or a combination of these factors, is enhanced when body carbohydrate stores can keep pace with fuel needs.

The body's carbohydrate supplies come from glycogen stored inside the muscle and from blood glucose which is topped up by liver glycogen stores or by carbohydrates consumed just before and during exercise. These stores can be turned over by a single exercise session of sufficient length and intensity (e.g. 60-90 min of high intensity training), so daily carbohydrate intake determines how much carbohydrate fuel is available for each training and competition session in the athlete's program.

Twenty years ago, sports nutrition guidelines promoted a universal message that all athletes should eat diets highly focussed on carbohydrate-rich foods at all times. These messages have changed in the light of new evidence, new understandings and new terminology.

Unfortunately, not all athletes and coaches have heard of these changes. Further confusion is provided by the current best-selling diets in the general community – for example Paleo, Atkins, Real Meal Revolution (high fat, low carb) and Zone – which are reduced carbohydrate, carb-restricted or entirely anti-carbs. This creates the need for some new and clear messages about carbohydrate and the athlete.

New concepts in carbohydrate guidelines for the everyday diet

A pictorial summary of guidelines for carbohydrate intake is provided in *Figure 1*, while the features of the updated guidelines are explained below:

1. We no longer promote a *"one size fits all"* approach to dietary carbohydrate targets. Instead, the athlete's carbohydrate intake should be individualised to suit the demands and goals of their training program. The frequency, duration and intensity of training will largely determine the muscle's carbohydrate needs, and that will vary between athletes.

2. We use different language and concepts to discuss carbohydrate intake goals. Targets for carbohydrate are provided in terms of grams relative to the athlete's size (body mass) rather than as a percentage of total energy intake. Furthermore, rather than simply talk about *"high carbohydrate diets"* and *"low*

carbohydrate diets", we should consider carbohydrate intake in comparison to the muscle's fuel needs on a daily basis. We should consider whether the total intake and timing of the day's intake able to meet the fuel demands of a workout (= high carbohydrate availability), or are carbohydrate stores depleted or sub-optimal in comparison to the muscle fuel demand (= low carbohydrate availability). Because each athlete's fuel needs can be different, any given carbohydrate intake might provide high carbohydrate availability for one athlete but low for another.

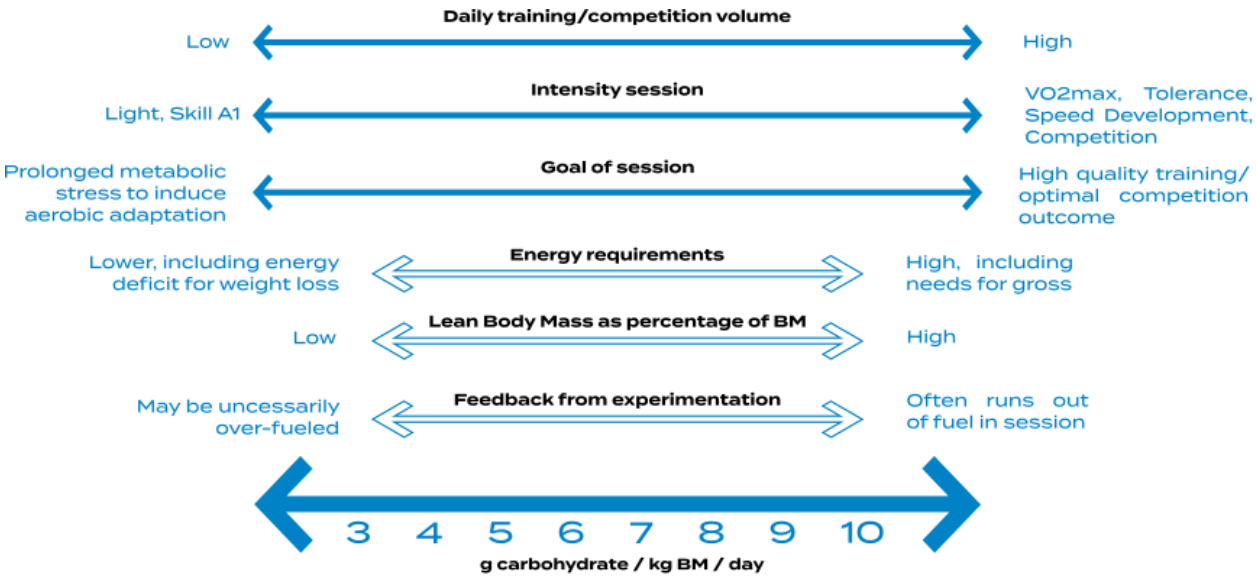
3. A fundamental principle of training is that the load and goals change from day to day, over the various microcycles and macrocycles in the periodised training calendar, and at different points of the athlete's career. Therefore, rather than having a static dietary intake, athletes should vary their carbohydrate intake from day to day according to the rise and fall in muscle fuel needs.

4. The central idea that carbohydrate is a key fuel for sports performance remains a constant. In many types of sport, the depletion of carbohydrate stores is associated with fatigue, an increased feeling of effort to sustain a given workload and reduced performance. Therefore, when it is important to train hard, at high intensity or with high quality, athletes should follow a range of dietary strategies that match their body's carbohydrate supplies to the fuel needs of their exercise program. This is obviously important in competition scenarios but should also be implemented for key training sessions or important training phases where high volume workload is in place and/or high-quality performance is required.

5. On other occasions, it may not be as important to train with high carbohydrate availability. Many athletes do some of their training sessions with low carbohydrate availability. Sometimes this is because of practicality – for example, swimmers often do their early morning training sessions without anything to eat. Sometimes, it is deliberate - the athlete may be reducing their carbohydrate and energy intake to reduce body fat levels. This may not be a problem during the base phase of training or on days of light training, when training intensity and quality is low. In fact, some studies suggest that doing some training sessions in this way provides a good stimulus to the muscle to help it adapt to training. Of course, such strategies need to be periodised into the training program so that they don't interfere with training intensity.

6. Even though daily carbohydrate targets (see Figure 1) can be developed from the features above, it is always important to fine-tune based on further individual considerations. Feedback from training should be considered (how am I performing? How am I feeling during a workout? Am I recovering sufficiently between sessions? Is illness or general fatigue a problem?). The athlete's energy budget is also important – there may be more room or need to increase carbohydrate during periods of growth or other high energy demand, but scenarios of reduced energy demand may require a tightening of carbohydrate targets.

Considerations in setting daily carbohydrate intake targets for aquatic athletes



Muscle glycogen less limitng for completion of session
Less need for carbohydrate intake over total day or around sessions
Some sessions may be deliberately done with low carbohydrate availability

High muscle glycogen requirement for completion of training or optimal competition performance

Promote opportunities for carboyhydrates intake in total day and around session

Practical suggestions for planning meals and snacks to assist with carbohydrate targets

- Many nutritious carbohydrate-rich foods can be included in meals and snacks to meet carbohydrate intake goals as well as contribute to overall diet quality
  - Wholegrain forms of breakfast cereals, oats, breads and crackers
  - Grain-based foods such as rice, pasta, quinoa, noodles
  - Fruits, legumes, and starchy vegetables
  - Sweetened dairy products (flavoured milk, yoghurts etc)

- A great way to track carbohydrate intake with muscle fuel needs is to include additional carbohydrate in meals or snacks eaten before and after a workout. This means when training needs increase, so does carbohydrate intake. Consuming carbohydrate before and during lengthy pool sessions will also add to the day's carbohydrate target as well as specifically provide fuel for the workout. Open water swimmers should particularly take this opportunity to practise their strategies for eating and drinking during their races.
- When athletes train more than once per day and sessions are close together, speedy recovery of the muscle carbohydrate stores may be important. Consuming carbohydrate-rich foods and drinks soon after the session helps with rapid refueling – a target of 1 g per kg of body mass per hour for the first 4 hours will optimize glycogen storage. The type of carbohydrate is generally less important than the amount, and athletes should make choices based on convenience, palatability, cost, and the contribution these foods can make to other nutritional goals.
- When it isn't possible to meet these carbohydrate targets during the early hours of recovery, or when the recovery period is short, the presence of protein in recovery snacks is likely to promote higher rates of glycogen storage than carbohydrate alone. This is useful since post-workout protein intake addresses other goals of recovery eating. Some protein-carbohydrate combinations are found in the section on Protein
- During longer recovery periods (24 hours), the pattern and timing of carbohydrate-rich meals and snacks does not appear to be critical, and can be organised according to what is practical and comfortable for each athlete.

Carbohydrates
For competition

The high-intensity nature of most pool events, as well as the whole body (arms and legs) contribution to performance, means that effort should be directed to preparing muscle glycogen stores to fuel good performances.

In pool swimming, artistic swimming, water polo and diving, well-chosen eating strategies can prepare the needed fuel supplies for each session, although it may be challenging to refuel between several sessions in a multi-day program, or between several races within the same session.

In open water races of longer than 1 hour, the depletion of muscle glycogen stores within the race poses a performance challenge, and nutrition strategies before and during the race will be needed to provide additional carbohydrate to keep the brain and muscles working optimally.

Strategies for competition eating include the intake of carbohydrate in the hours or days prior to an event to ensure muscle and liver glycogen stores are appropriately stocked for the fuel needs of the event, consuming additional carbohydrate during longer events, and proactive refuelling in the period between multiple events.

In the absence of muscle damage, the aquatic athlete can normalise their muscle glycogen stores with as little as 24 hours of carbohydrate-rich eating and exercise taper. The targets identified in the previous figure can be used to guide pre-event preparation.

It should be remembered that many aquatic athletes undertake a pronounced taper in the pre-competition phase – carbohydrate targets should be based on real competition needs (the fuel demands of the event and continued training within the competition phase) rather than on previous patterns of high-volume training.

"Carbohydrate-loading"

Open water swimmers who compete in races of 10 km and longer may benefit from *"carbohydrate-loading"* for a few days prior to the competition. This strategy involves consuming carbohydrate at intakes known to maximise glycogen storage (9-12 g/kg/d) for 24-48 hours while exercise is reduced to an easy taper. This strategy allows muscle glycogen stores to be super-compensated above normal levels to fuel the lengthy demands of their race. It can sometimes be challenging to re-load between races when the swimmer competes in both 10 and 25 km races on a competition program.

Pre-event meal (1-6 h period before competition)

Athletes should try to find a range of foods to eat in the hours prior to competition that

not only provide extra energy during the event, but also feel *'right'* in terms of curbing hunger, maintaining gut comfort, and being convenient as well as practical. In aquatic sports that do not cause carbohydrate depletion (e.g. diving), the pre-event meal need not be carbohydrate-focussed. However, in events involving greater muscle fuel demands, athletes are advised to use the pre-event meal to top up carbohydrate stores. This is especially important if recovering muscle glycogen from a previous competition session, or in the case of morning events, to top up liver glycogen stores after fasting overnight.

The effect of eating carbohydrate in the hours before exercise is to increase the muscle's rate of carbohydrate use. Therefore, the pre-event meal should contain enough carbohydrate to compensate for this *"priming"* of greater carbohydrate reliance.

A carbohydrate intake greater than 1 g/kg should achieve this goal, and pre-event meals which enhance performance in longer events are generally in the range of 1-4 g/kg carbohydrate.

Continuing to consume carbohydrate during a longer event, such as a water polo game or open water race helps to sustain fuel availability.

Depending on the time of day, the athlete's preferences and the availability of food, an athlete may choose a range of carbohydrate-rich foods and drinks to make up their pre-event meal. The type, timing and amount of foods should be practiced until a successful plan is developed.

Carbohydrate intake during exercise

During water polo and open water swimming, there is both opportunity and a potential benefit from consuming extra carbohydrate during the event. We have long recognised that consuming carbohydrate during exercise enhances performance - with benefits seen in terms of sustaining optimum pace, allowing more time at high intensities, and maintaining mental skills and concentration. A variety of mechanisms seem to explain this, ranging from providing high rates of an additional fuel to the muscle to making the brain feel happy so that it feels able to make us work harder.

Until recently, we have provided a generic recommendation for carbohydrate intake during exercise. However, there is now good evidence that exercise of different duration and intensities requires a different carbohydrate feeding approach (*see Table A below*). A range of carbohydrate-containing drinks and foods may be able to supply these targets, as well as other needs such as fluid. These include special sports products such as sports drinks, gels and bars. Many everyday foods and drinks such as fruit, juices and soft drinks and confectionery may also be suitable. The athlete should practice in training to develop a race or event fuelling plan. This plan will need to take into account the opportunities provided in the athlete's event to consume drinks or foods.

Refuelling between events

The competition schedule in many aquatic sports involves multi-events in the same day or multi-date competition. Therefore, some preparation will be needed to ensure that the athlete has adequate access to carbohydrate-rich snacks and meals to appropriately refuel between their events. Having well-chosen snacks and specialised sports drinks/foods at the pool may be an important part of the plan, particularly if the athlete's timetable at the pool needs to include warm-downs, media appearances, drug testing and other activities. Again, the athlete should refuel according to their real needs rather than adopting either over-zealous or lazy (unplanned) approaches.

Event	Duration	Carbohydrate target	Comments
During sustained high intensity exercise (e.g. water polo game or 5 km open water race)	45-75 min	Small amounts (including simply swilling carbohydrate around the mouth)	✓ Opportunities to consume carbohydrate-rich foods and drinks vary according to the event – from feeding pontoons or choices carried by the swimmer during open water races, to pool-side supplies for game breaks and substitutions during water polo ✓ A range of everyday dietary choices and specialised sports products ranging in form from liquid to solid may be useful
During endurance exercise (e.g. 10 km open water race)	1-2.5 h	30-60 g/h	✓ Higher intakes of carbohydrate are associated with better performance and swimmers should make use of feeding pontoons to gain supplies ✓ The athlete should practice to find a refuelling plan that suits their individual goals including hydration needs and gut comfort ✓ Practice with the choice of carbohydrate and feeding strategies is important
During ultra-endurance exercise (25 km race)	> 2.5-3 h	Up to 90 g/h	✓ As above. ✓ Products providing multiple transportable carbohydrates (Glucose:fructose mixtures) will achieve high rates of oxidation of carbohydrate consumed during exercise

Table A

Dietary protein for athletes
From requirements to optimum

Protein needs in sport are another area in which knowledge and practice have evolved.

For many years there has been debate about the total protein requirements of athletes, with many experts believing that daily needs are elevated above those of sedentary people. Protein intake targets for both strength and endurance training have been set at about 1.3-1.8 g/kg body mass per day.

Most dietary surveys show that most athletes following *"western"* diets easily meet these goals, even without the intake of expensive supplements. Athletes who are most at risk of failing to meet these targets are those who restrict their energy intake and food variety.

The new way to consider protein needs, however, is to consider the role of protein in achieving the desired outcomes of each training session, since each session ultimately promotes the building of new proteins in response to the specific type of training.

Dietary protein plays an important role in this response to exercise. The amino acids that make up the proteins in the foods that we eat are used as the building blocks for the manufacture of new tissue, including muscle, and for the repair of damaged tissue. They are also the building blocks for hormones and enzymes that regulate metabolism, support the immune system and other body functions. Protein provides only a small source of fuel for the exercising muscle but does increase when muscle carbohydrate stores are low.

When this approach to protein needs is taken, the focus becomes how to promote optimum protein synthesis in the period of recovery and adaptation from each workout.

The following ideas have emerged:

- Eating a source of high-quality protein soon after exercise is part of the process of promoting muscle protein synthesis. High quality protein, particularly from animal sources (e.g. dairy, meats, eggs etc), is especially valuable
- The amount of protein required to maximise this response to exercise is quite modest – about 0.3 g per kg Body mass (typically, 20-25 g)
- It may help to choose a protein source that is rapidly digested and provides a good source of leucine as the post-workout protein boost. Whey protein fits this profile, which explains its popularity for post-workout recovery. This can easily be found in everyday dairy foods and drinks. Nevertheless, sometimes there can be value in using a more compact form that is easy to carry and prepare

around the exercise session – such as a liquid meal supplement or a simple protein powder. There is no justification for the more expensive protein powders or amino acid formulations with extra ingredients and fancy claims

- We know that the muscle is stimulated to increase its protein synthetic rates for up to 24 hours after a workout. The best way to take advantage of this is to spread protein serves (20-25 g) over meals and snacks consumed 4-6 times over the day. This is not something that our traditional eating patterns always achieve, since most people eat the majority of their protein intake at the evening meal. It may be more sensible to redistribute protein intake to other meals in the day
- When high volume training, growth and an aggressive approach to gain of muscle mass is required, it can help to have an extra serve of protein in the day, just before bed.

Protein rich foods 10 g protein is provided by each choice	Examples of nutrient-rich carbohydrate and protein combinations for refuelling and rebuilding after key sessions
✓ 2 small eggs ✓ 300 ml cows' milk ✓ 30 g cheese ✓ 200 g yoghurt ✓ 35-50 g meat, fish or chicken ✓ 400 ml soy milk ✓ 60 g nuts or seeds ✓ 120 g tofu or soy meat ✓ 150 g legumes or lentils ✓ 150 ml fruit smoothie/liquid meal	✓ Breakfast cereal with low fat milk ✓ Baked beans on toast or on a baked potato ✓ Fruit salad with fruit-flavoured yogurt ✓ Bagel with peanut butter + low fat milk ✓ Fruit smoothie or liquid meal supplement ✓ Low Fat chocolate milk ✓ Lean meat and veggie pizza ✓ Sandwich with meat and salad filling ✓ Meat and vegetable stir fry with noodles or rice

Vitamins, minerals and antioxidants

Vitamins are chemicals that help the body to function smoothly by supporting metabolism. The essential minerals (sodium, potassium, iron, magnesium, etc) also play a range of roles to ensure a stable environment for the body to function, in muscle contraction, nerve conduction, oxygen transport and all of the other processes that keep us alive. Other minerals form important tissues such as the calcium in bones.

Some vitamins and minerals and other nutrients also have a role as anti-oxidants to mop up the free oxygen radical chemicals that are formed as a by-product of metabolism. In short, they are important for maintaining optimum health and function.

Athletes often want to know if their training programs create special needs for additional intakes of vitamins and minerals. It is likely that this might be the case for at least some nutrients, but that a well-chosen and varied diet based on adequate energy intake is easily able to meet any increased demands.

Athletes who are training hard and who eat enough foods to meet their increased energy needs will generally achieve high intakes of all of the essential nutrients from the foods that they eat. Dietary surveys show that most athletes are well able to meet the recommended intakes for vitamins and minerals by eating everyday foods.

Those at risk of sub-optimal intakes of these micronutrients include:

- athletes who restrict their energy intake, especially over long periods, especially to meet weight loss goals
- athletes who follow eating patterns with restricted food variety and reliance on foods with a poor nutrient-density

The best way to correct this situation is to seek advice from a sports nutrition expert such as a sports dietitian. When food intake cannot be adequately improved – for example, when the athlete is travelling in a country with a limited food supply - or if an individual is found to be suffering from a lack of a particular vitamin or mineral, then short-term supplementation might be appropriate. This should be undertaken with the advice of a qualified sports nutrition expert. In general, a broad-range multivitamin/mineral supplement is the best choice to support a restricted food intake, although targeted nutrient supplements may be necessary to correct an established nutrient deficiency.

Some special micronutrients and other food chemicals will now be discussed.

Anti-oxidant nutrients

We know that free oxygen radicals are produced during normal metabolism, and that our bodies develop anti-oxidant defence systems to neutralise these

chemicals and the damage they cause to body tissues.

We also know that exercise causes an increased production of these oxygen radicals, and many athletes feel that anti-oxidant supplements may help to protect them against this elevated level of harm.

Vitamins C and E supplements have been popularly used for this purpose.

More recently, however, there have been changes to such thinking. It seems unnecessary to provide large doses of a few anti-oxidant chemicals when the body has its own mechanisms to increase a more complex antioxidant defence system. In fact, it may simply unbalance the system and cause more harm than good.

There may be some benefits associated with the production of free oxygen radicals – new evidence shows that they function as signals to promote important adaptations to training. It is possible that the use of antioxidant supplements may actually neutralise some of the signalling that underpins recovery and adaptation to a workout, meaning that antioxidant supplementation could reduce the effectiveness of a training program.

Foods contain a large variety of health promoting chemicals in addition to vitamins and minerals. These products – usually called phytochemicals or phytonutrients – promote function and health in our bodies as antioxidants, anti-cancer agents, and many other roles. The names of some of the chemicals include quercetin and ECGC, and new studies are continually investigating whether supplemental forms of these products could be useful for health and performance. To date, these studies haven't been able to translate the benefits known about these products into a functional output. Therefore, at present, the most effective way to approach these chemicals is though eating them in plentiful amounts in food.

Ideas for promoting dietary variety and nutrient-rich eating to achieve a plentiful intake of vitamins, minerals and phytochemicals

- ✓ Be open to trying new foods and new recipes
- ✓ Make the most of foods in season
- ✓ Explore all the varieties of different foods
- ✓ Mix and match foods at meals
- ✓ Think carefully before banishing a food or group of foods from your eating plans
- ✓ Find substitution foods that have similar nutrients when excluding a food group
- ✓ Include fruits and/or vegetables at every meal and snack. The strong and bright colours of many fruits and vegetables are a sign of a high content of various vitamins and other food anti-oxidants. Aim to fill your plate with a rainbow of highly coloured foods to ensure a good intake of the range of these health-promoting dietary compounds

Vitamin D

Vitamin D is classified as a fat-soluble vitamin which acts as a hormone.

It has important functions in the body including maintenance of good bone health, muscle function and immunity.

Vitamin D is found in some foods, but our major source comes from sunshine exposure.

Vitamin D deficiency can lead to several health issues including increased risk of bone injuries, chronic musculoskeletal pain and viral respiratory tract infections. Reversal of sub-optimal Vitamin D status in

athletes may have beneficial effects on athletic performance and health.

Athletes at risk of Vitamin D deficiency include those who:

- train indoors
- have dark skin
- live further away from the equator
- wear clothing that covers most or all of their body
- regularly use sunscreen or consciously avoid the sun

Such athletes should be screened and if Vitamin D levels are sub-optimal, a course of Vitamin D supplementation, and perhaps judicious sunshine exposure should be undertaken under medical supervision.

Iron

Iron plays an important role in the transport of oxygen in the blood (as haemoglobin) and muscle (as myoglobin), and inadequate iron status can obviously impair performance and recovery.

There is some evidence that an athlete's iron requirements may be elevated due to increased levels of loss due to their training load. However, most athletes who become iron deficient or anaemic do so because of poor iron intake.

Athletes who are at high risk of such problems are those who restrict energy intake and dietary variety. Since meats are a major source of well absorbed iron, vegetarian eaters will need to plan their meals carefully to find alternative iron sources.

Females are also at risk because of increased iron requirements due to menstrual blood losses matched against a smaller food intake. Iron-rich eating will help to reduce this risk.

Athletes who are at risk of poor iron status should have this monitored periodically.

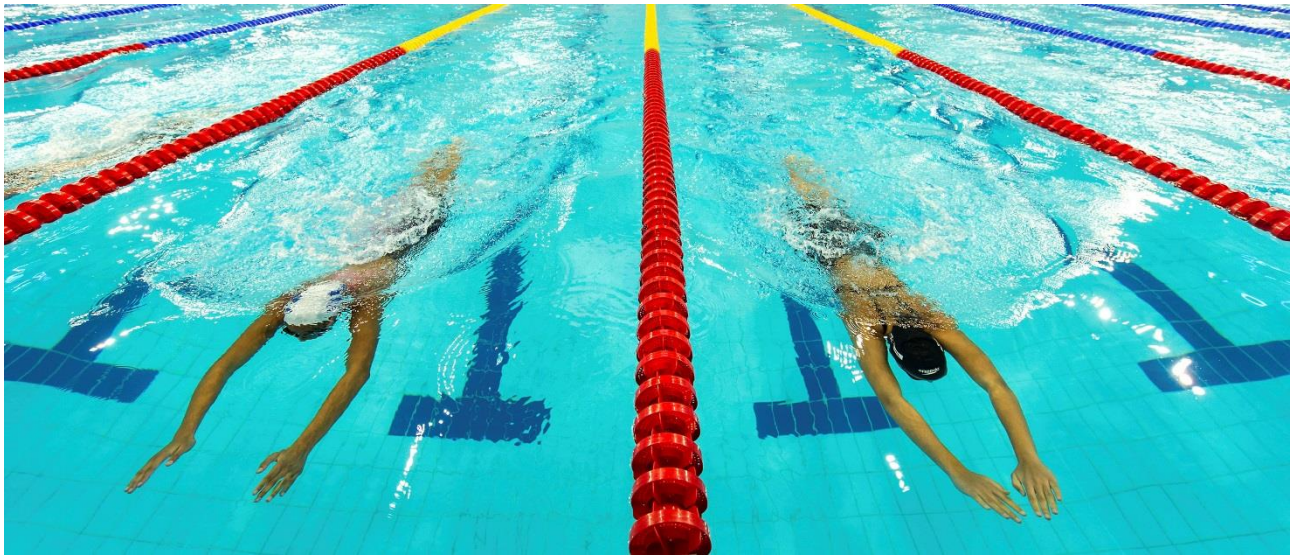
Athletes who are undertaking altitude training often like to do this too, to ensure that they have sufficient iron stores to allow the adaptations to their specialised training demands.

Routine use of iron supplements is not wise: too much is just as harmful as too little. Self-medication with iron supplements may not address the real causes of an athlete's fatigue or other issues of poor eating and may do more harm than good.

Calcium

Calcium is important for healthy bones, especially in adolescents and in female athletes, so it is important to ensure adequate calcium intake.

The best sources are dairy foods, including low fat varieties.



Iron-rich eating strategies

- ✓ Consume moderate servings of red meats (well-absorbed iron) in 3-5 meals per week
- ✓ Choose iron-fortified cereal products such as breakfast cereals
- ✓ Combine plant and non-meat sources of iron (e.g. legumes, cereals, eggs, green leafy vegetables) with food factors that enhance iron absorption. These include vitamin C and a factor found in meat/fish/chicken. Examples of clever matching include fruit juice or fruit with breakfast cereal, or chilli con carne (meat and beans)
- ✓ Avoid combining non-meat source of iron with food factors that inhibit iron absorption such as phenolic compounds (e.g. team and coffee), phytates (e.g. bran), or calcium (e.g. dairy)

Calcium

- ❖ Each athlete should aim to include at least 3 servings of these foods in their daily eating plans such as:
  - ✓ glass of milk
  - ✓ slice of cheese
  - ✓ carton of yoghurt
- ❖ Additional daily servings are required during growth spurts in childhood and adolescence, and for pregnancy and lactation
- ❖ Fortified soy foods may provide a useful substitute where athletes cannot consume dairy foods

Hydration:
Water and salt needs for training, competition and recovery

The water and salt needs of athletes are dictated primarily by three factors:

1. The normal losses of daily living, including losses in urine, faeces, breath and through the skin.
2. Increased losses caused by training (in the water and on land) as a result of increases sweat and respiratory losses.
3. The environment: there are increased losses during periods of warm weather and at altitude.

Aquatic athletes are unique in relation to fluid needs.

Undertaking most of your training immersed in water causes some interesting features related to hydration issues.

First, sweat losses are highly variable and are greatly influenced by the temperature of the water in which the activity is undertaken. When the water is cool, as dictated by the FINA temperature requirements for competition pools (25-28°C), a lot of the body heat produced during exercise can be dissipated by convection in the water, reducing the need to sweat.

Thus, the sweat losses typically incurred by aquatic athletes are lower than those seen in land-based sports of a similar intensity/duration.

However, open water swimming has more variable water temperatures (16-31°c; as dictated by World Aquatics rules) and can have a greater impact on hydration status.

Nevertheless, the second point is that being in and out of the water, as occurs in many aquatic activities, can camouflage actual sweat losses since it can be difficult to distinguish where the water on skin, costumes and hair is coming from.

Therefore, some aquatic athletes are not aware of fluid as an issue of general interest and can under-estimate their true sweat losses during a workout or race. Many may not be aware that significant losses can occur during sessions that are high in intensity, undertaken in a hot indoor or outdoor environment, undertaken in a hot pool or waterway or combined with dry-land training.

Finally, as we will explore later, some of the features associated with aquatic sport challenge the accuracy and practicality of implementing the simple measurement used by many athletes to assess fluid losses over the session: monitoring weight changes over the workout and the volume of fluid consumed from a personal drink bottle.

All these features may challenge the athlete's ability to look after their hydration needs around exercise, with the capacity both to overhydrate and under-drink.

Doing a better job means learning the practical aspects of:

- when it may be helpful to drink during a workout or event
- how much to drink
- what type of drinks are best, and
- what modifications should be made in hot or cold environments, especially in the case of open water swimmers

Just as general training and competition strategies should be tailored for individual athletes in accordance with their unique needs and preferences, so should their drinking and eating choices during exercise. Athletes, coaches and trainers should *'fine tune'* the following recommendations to identify their own winning formula.

When is it helpful to drink during exercise?

Fluids consumed during exercise can play a number of roles. These include making the athlete feel more comfortable, replacing a body fluid deficit, and providing a means to consume other ingredients such as carbohydrate. The importance of each of these roles will vary according to the situation.

It is seldom necessary to replace fluid losses during exercise that lasts less than about 40 minutes, but even in some short workouts or competitive events, some athletes feel better after having a drink and this should do no harm.

During training or competition sessions lasting longer than about 40 minutes, however, there may be advantages to drinking during the session. When it is not possible to drink during such sessions, an alternative is to hydrate well just before starting the session. To do this, the athlete should practise drinking during the 15 minutes before exercise and find how much is initially filling but comfortable once exercise begins (e.g., 300-800 ml).

How much to drink?

How much you should drink during exercise depends on a number of factors including the size of the fluid deficit that your sweat losses are contributing to as well as the comfort and practicality of your opportunities to drink.

A small fluid deficit (e.g. < 2% Body Mass) has no effect on performance, but severe dehydration (e.g. > 5% BM) impairs exercise intensity and quality as well as mental skills.

There is no clear evidence on the point at which performance begins to be affected and this almost certainly varies between individuals as well as depending on the type and duration of exercise and on the environmental conditions.

Athletes are often advised to drink only when thirsty, but this may not always be a reliable guide. Furthermore, the rules and opportunities to drink fluids in many sports may not coincide with the times that thirst hits.

A more targeted option is to develop a fluid plan to fit the event, the individual and other nutritional needs.

As a starting point, the athlete should try to drink at a rate that replaces enough of their sweat losses so that the overall fluid deficit for a training session or competition is kept to no more than about a 2% loss of body weight (i.e. 1.0 kg for 50 kg person, 1.5 kg for a 75 kg person, and 2 kg for a 100 kg person). This is usually achievable in aquatic sports.

The exception may be in open-water or distance swimming over long duration sessions in warm water/environments when sweat rates are high and it is difficult to get access to fluid. When it isn't practical to drink

enough to keep fluid deficits below this target, a more feasible alternative is simply to try to minimize dehydration.

In some situations, athletes over-hydrate during exercise – drinking more than their sweat losses. There may be some reasons when this is justified; for example, the case of the athlete who starts a workout or event already dehydrated.

However, problems can occur when the fluid intake is excessive, leading to a serious problem called hyponatraemia (dilution of blood sodium concentrations). This is most often seen in recreational exercisers who work at low intensities but drink large volumes of fluid in the belief that they are doing the right thing.

In all of these situations, it can help for an athlete to have a feel for their typical sweat rates and how hard or easy it is to drink to keep pace with these. The guide below provides some ideas on to how to check this.

When do you need more than water?

Although hydration is a key focus of nutrition strategies during exercise, fluids consumed during exercise can contain a range of ingredients. In terms of proven performance benefits, no nutrients match water and/or carbohydrate.

During exercise lasting longer than 1 hour and which elicits fatigue, athletes are advised to consume a source of carbohydrate that is rapidly converted to blood glucose. This generally improves performance – allowing the athlete to maintain pace, skills and concentration instead of succumbing to fatigue. As outlined in the earlier section on Carbohydrates in competition, the targets for carbohydrate during exercise will vary according to the athlete's preparation (how well fuelled), the fuel needs of the event (duration and intensity of the session) and individual tolerance.

The use of commercial sports drinks with a carbohydrate content of about 4-8% (4-8 g/100 ml) allows carbohydrate and fluid needs to be met simultaneously in many events. The small electrolyte content of these drinks preserves thirst and acknowledges that sweat is also a source of body electrolyte loss.

As previously outlined, in other events where sweat losses may be lower but muscle fuel needs are still high, more concentrated carbohydrate choices (e.g. gels and confectionary) may be useful to fuel without overhydrating.

Typically, when carbohydrate is consumed during exercise, it is best consumed in a pattern of frequent and continued intake. This will provide a constant stimulation of the brain and central nervous system, or when needed, a constant source of additional fuel for the muscle.

Caffeine contained in commonly available beverages and foods can enhance endurance or performance during the later stages of prolonged exercise.

This benefit can be obtained with relatively small doses of caffeine (about 2-3 mg/kg bodyweight or 100-200 mg caffeine). This is equivalent to 1-2 cups of brewed coffee or 750-1500 ml of a cola beverages as commonly consumed by people of various cultures.

Various sports products (gels, drinks etc) may also provide a convenient low dose serve of caffeine.

Contrary to popular belief, when caffeine is consumed in these amounts it has little effect on urine losses or hydration.

Rehydration after exercise

Replacement of water and the salts lost in sweat is an essential part of the recovery process that prepares an athlete for their next exercise session.

Since sweat and urine losses continue to occur during recovery, the athlete will need to drink about 1.2-1.5 litres of fluid for each kg of weight loss in training or competition to compensate and fully restore fluid losses.

This may not be an issue for sessions when sweat losses were moderate and there was plenty of opportunity to drink during the session. However, in hot weather and after prolonged high-intensity training sessions, a rehydration plan may be useful.

Sodium, the main salt lost in sweat, also needs to be replaced. Sodium replacement can be achieved via sodium-containing fluids such as sports drinks and pharmacy oral rehydration solutions.

However, a well-chosen meal or snack can supply the salt that is needed.

This may be because the foods are salt-containing (e.g. breads, breakfast cereals, cheese, processed meats) or because salt is added in the preparation or serving of the meal.

Practical ways to assess and manage hydration

Every athlete is different because they have different sweat losses and different opportunities to drink fluid during their workouts and events. The goal is to develop hydration plans that are individualised to specific situations, and avoid excessive levels of both over- and under-hydration. Strategies that can be used periodically to assess sweat losses and hydration levels provide a valuable role in developing such plans.

Two simple steps may help to guide your hydration practices

1. In scenarios or environments where sweat losses are high, aim to start each exercise session well hydrated. If you are passing urine less often than normal, you may be dehydrated. If urine colour becomes darker than what is normal for you, then you may not be drinking enough. Check your urine colour against the chart.
   Note that the aim should NOT be for your urine to be as pale as possible. Drinking too much can be uncomfortable and, if excessive, possible harmful. The aim is to develop fluid practices over the day whicht keep pace with regular fluid needs and special losses from exercise or hot environments. As losses change, so should drinking practices. It makes since to spread fluid intake over the day rather than trying to play catch up at the end. Drinking more than you need in the late part of the day can mean interrupted sleep due to toilet breaks.
2. Develop a drinking plan for training and competition that is right for you. This should be based on several pieces of information including your typical sweat losses, the opportunities to drink in your sport, and feedback from comfort and thirst.
   Monitor your sweat losses and the success of your drinking plan during training sessions in different situations (see box). How did you feel? How did you perform? What was your weight loss over the session? This should generally not exceed about 2% of body mass. If you lost more than this, you probably did not drink enough. Drink more next time. If you lost less, you might have drunk too much. Did it make you feel uncomfortable? Did you take time out to drink that was unnecessary?

   Drinking so much that you gain weight during competition is never likely to be a

good idea. The only time you might need to do this is when you have been dehydrated at the start of the event.

How to estimate sweat losses and sweat rates:

1. Measure body weight both before and after at least one hour of exercise under conditions similar to competition or a hard workout.
2. Take these body weight measurements wearing minimal clothing and while bare footed. Take the "Before" exercise measurement just before commencing the session, and after going to the toilet. For the "After" measurement, towel dry after exercise and obtain body weight as soon as is practical (e.g. less than 10 min after the session, and before eating, drinking or going to the toilet).

   Note: your wet hair and swimming costume are likely to be carrying water weight, even after your have towelled yourself. This will vary according to the individual, but tends to be more of a problem for female athletes. Greater accuracy can be gained if the pre-training weight is also measured under the same conditions – that is, shower before the session or dive in the pool and get wet then towel-dry.

Example: Pre-exercise weight = 74.5 kg

Post-exercise weight = 72.8 kg

Fluid deficit = 1.7 kg

3. Estimate the weight of any fluid or foods you have consumed during the workout

Example: 800 ml of fluid = 800 g or 0.8 kg

Note: it may not always be possible to account for all fluid consumed during the session since water may be accidentally swallowed from the pool. This error will underestimate fluid losses and sweat rates from the calculation guidelines provided here

4. Sweat loss (Litres) = Body weight before exercise (in kg) - Body weight after exercise (kg), + weight of fluids/foods consumed (kg).

Example: 74.5 kg – 72.8 kg = 1.7 kg deficit

+ 0.80 kg (800 ml fluid) = sweat loss of 2.5 kg or 2500 ml.

Note: various characteristics of swimming tend to promote urine production – most aquatic athletes know of the urge to visit the bathroom during a workout. If this occurs, you should try to estimate the volume of urine lost – either, weigh yourself before and after the bathroom visit, or in the case of a research protocol where extra accuracy is required, collect the urine in a container so that you can measure the volume. This volume/weight should be subtracted from the pre-post session weight change to correct it to reflect sweat losses more accurately.

5. To convert sweat loss over the session to a sweat rate per hour, divide by the exercise time in minutes and multiply by 60.

Example: sweat loss of 2500 ml in 100 min session = 2500/100 x 60 = 1500 ml/hour

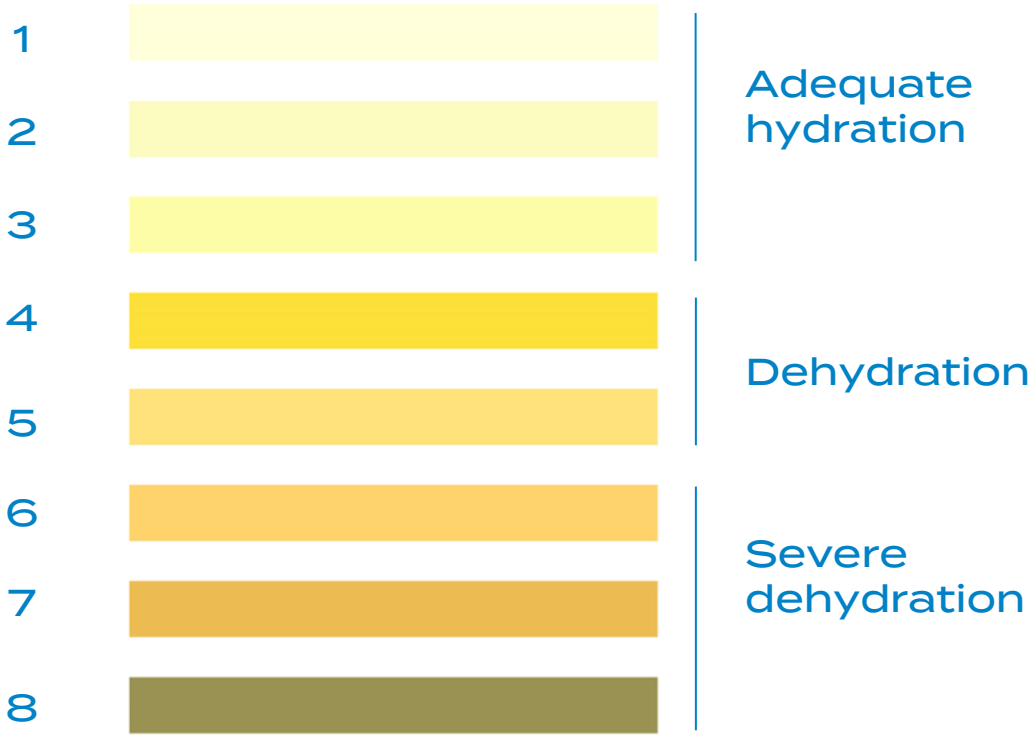
6. Your weight deficit at the end of the session provides a guide to how well you hydrated during the session, and how much you need to rehydrate afterwards.

To convert kg to % body weight, divide the weight deficit by starting body weight and multiply by 100:

Example: 1.7 kg/74.5 X 100 = 2.3%

Note: 2.2 pounds equals 1.0 kg and converts to a volume of 1.0 litre or 1,000 ml or 34 ounces of water

Chart on urine colours



Supplements and sports foods

Many athletes in the aquatic disciplines look to sports foods and dietary supplements for health and performance benefits, including:

- modifying physique – gaining muscle mass or losing body fat
- providing a fuel supply for the workout or race
- allowing more consistent and intensive training by increasing vigour during a workout or promoting recovery between sessions
- promoting adaptations to training
- maintaining good health and reducing interruptions to training due to chronic fatigue, illness or injury
- enhancing competitive performance
- addressing a nutrient deficiency
- Providing a convenient source of nutrients that is easy to consume when everyday foods are unavailable or impractical to eat. This is most often the case just prior to, during, or after an exercise session, or sometimes when travelling.

Some of these products may have benefits for some aquatic athletes, but this will depend very much on the discipline, the performance level, the training status and also on the biochemistry and physiology of the individual.

Sports foods are generally manufactured to achieve the last of these goals, and by providing a practical way to meet special nutrition needs they may indirectly assist the athlete to achieve some of the benefits on the list.

Examples of sports foods that might be useful include:

- sports drinks (providing fluid and carbohydrate during exercise)
- sports gels (additional carbohydrate intake, especially during exercise)
- liquid meals (carbohydrate, protein, vitamins and minerals for a pre-event meal, post-exercise recovery or a high-energy diet)
- sports bars (carbohydrate, protein, vitamins and minerals – often a solid form of the liquid meal)
- protein powders (high quality protein source that can be mixed with water into a drink or added to other fluids such as milk or fruit smoothies to boost the protein content)

Of course, the cost of these sports foods must be taken into account when deciding to use them. Furthermore, the athlete should

recognise that the sports food market includes products that are carefully manufactured to provide nutrients to meet well documented goals right through to gimmicky items that have a poor composition or the addition of ingredients with no evidence base.

The use of pills, potions, powders and other sports supplements is widespread, but few products are supported by sound research and some may even be harmful to the athlete.

Athletes should look carefully at the risks and rewards of individual supplements before trying them.

Where there is a demonstrated deficiency of an essential vitamin or mineral, and an appropriate intake from food is not possible, a supplement may be helpful.

For example, other sections of this booklet have noted that athletes with a diagnosed deficiency of iron or Vitamin D may benefit from a course of supplements, but this should be done only if a blood test shows it to be necessary.

The use of supplements, however, does not compensate for poor food choices and an inadequate diet.

A much better option is to develop the knowledge and skills to ensure that all your nutritional needs are met from a variety of well-chosen foods.

Protein powders and supplements

Protein supplements, high protein bars and amino acid preparations are among the biggest selling sports nutrition products.

An adequate intake of protein is essential for muscle growth and repair, but this can usually be achieved from everyday foods and expensive supplements are seldom required.

When there is a case for a more practical source of high-quality protein, the preferred protein supplements are:

- Protein-carbohydrate supplements (known also as liquid meal supplements). These provide an easily prepared and rapidly digested source of the major nutrients needed for recovery after exercise (helping with repair, rehydration and refuelling). In addition, they can provide an easily consumed source of energy in a high energy diet or while travelling
- A simple whey protein powder. Whey, as one of the high quality milk proteins, provides a rapidly digested source of leucine and other essential amino acids. This may be useful when repair and adaptation is the main recovery need, or when a quick fix is needed to add quality protein to a sub-standard meal. There is no evidence that fancy versions of whey protein with special preparation techniques or other ingredients are superior. A serve providing 20-30 g of whey protein is adequate to meet needs at a single meal or snack

Fat reduction and muscle building

A huge array of supplements is on sale with claims that they can reduce body fat levels and build bigger and stronger muscles – claims that appeal to athletes and non-athletes alike.

The reality is that many of the products that are effective in doing this are either on the WADA Prohibited List or are associated with serious health risks (or both).

Many weight-loss supplements have been shown to contain prohibited drugs that are not listed on the label, principally from the stimulant category. Many of the muscle building products contain banned prohormones and compounds related to testosterone or anabolic steroids.

These products can lead to an Anti-Doping Rule Violation.

Increasing energy supply and increasing training capacity

Pre-workout supplements or pre-trainers are an increasingly popular group of products which typically contain a large number of ingredients claimed to provide or enhance muscle fuel or increase vigour and capacity for training.

The ingredients include substances like creatine and B-alanine, which enjoy scientific support, but may not be provided in useful doses in the product. In fact, in many cases, the ingredient list of these products is hidden with the claim that it is a *"proprietary blend"*.

Unfortunately, this may also hide the presence of large amounts of caffeine and other stimulants.

Some of these other stimulants maybe on the WADA Prohibited List, and the type and amount of stimulants can cause health risks.

Other supplements or ingredients in this category include pyruvate and ribose as well as some more exotic herbal preparations. None of these is likely to improve performance and, in spite of advertising claims, none is supported by good independent evidence. There is now limited evidence that carnitine can affect exercise metabolism in some circumstances, but the evidence for performance effects is not yet convincing.

Nutrition and the immune system

There is some evidence that athletes who are training hard may be at increased risk of minor illnesses and infections. In themselves, these are generally trivial, but they can interrupt training or cause an athlete to miss important competitions.

Hard training may compromise the body's immune system, and high levels of stress hormones reduce its ability to fight these infections.

Many nutrition supplements, including glutamine, zinc, echinacea, colostrum and others, are on sale with claims that they can boost the immune system, but there is no strong evidence that any of these is effective.

The best strategies to support a healthy immune system include scheduling appropriate rest periods, and matching carbohydrate intake to fuel needs.

There is good evidence that carbohydrate intake during prolonged exercise reduces the release of stress hormones.

There is also emerging evidence that probiotics, such as the lactobacillus found in dairy products, may also assist gut health and the immune system.

Supplements for bone and joint health

Hard training puts extra wear and tear on the bones, joints and associated structures, and numerous supplements are claimed to look after these tissues. Healthy bones need a good supply of calcium and Vitamin D.

In most cases these nutrients can be supplied by a well-chosen diet and appropriate sunshine exposure.

Athletes who suffer from problems related to sub-optimal bone density should seek professional advice and supervised treatment from a sports physician. Low energy availability is often implicated (see section in this booklet).

Glucosamine, methylsulphonylmethane (MSM), chondroitin and other products are promoted for joint health. There is some evidence that long-term (2-6 months) glucosamine treatment can provide subjective relief in elderly individuals suffering from osteoarthritis, but evidence is lacking for a benefit such as a *"joint protective"* effect from high-intensity training in healthy athletes.

Supplements that might work

There is scientific evidence to support the prospect of improved performance following the use of some supplements in specific events, according to tried and tested protocols.

Of course, such use should be undertaken only with input from an appropriate sports nutrition expert and as part of a sports nutrition plan that prioritises "a food first" philosophy.

Creatine

Supplementation with creatine monohydrate can increase the amount of high energy phosphocreatine stored in the muscles, and may improve performance in single or multiple sprints.

It may also lead to a gain in strength and/or muscle mass, which is helpful for some athletes, but the extra weight may be harmful for others.

As with all supplements, exceeding the maximum effective dose is not helpful.

Creatine is normally found in meat and fish, but the effective doses (10-20 g per day for 4-5 days to load, and then 2-3 g per day for maintenance) are more than is found in normal foods.

Creatine supplementation does not appear to be harmful to health when taken in this way by otherwise healthy people.

Caffeine

A small amount of caffeine (1-3 mg/kg) can help performance in prolonged exercise and may also be helpful in exercise of shorter duration.

Such moderate doses can be found in everyday amounts of coffee, cola drinks and some sports products (e.g. gels).

For example, 100 mg of caffeine is supplied by a small cup of brewed coffee or 750 ml of a cola drink. Larger doses of caffeine do not seem to be more effective, and may have negative outcomes such as anxiety, gastrointestinal distress, over-arousal and poor sleep patterns after an event. This is likely to be a problem in multi-day events and in sports involving heats and finals.

Note that energy drinks – drinks containing sugar and caffeine- should not be confused with sport drinks which are designed to rehydrate the body during exercise. While energy drinks may seem refreshing and envigorating, they may be potentially dangerous if used in excess or in combination with other stimulants or alcohol.

Importantly, they may be tainted with prohibited substances, such as those derived from unregulated herbals.

Most drinks are not tested for purity or contamination, and could lead to a positive doping test.

Buffering agents

During very hard exercise, the muscles produce lactate and hydrogen ions (acidity). This is both good (giving energy to allow hard efforts) and bad (causing pain and interfering with muscle function).

In the same way that excess stomach acidity can be neutralised by taking bicarbonate, so can taking sodium bicarbonate (in a dose of about 0.3 g per kg BW) before an event provide the blood with extra capacity to buffer the acidity produced by the muscle.

This can reduce the fatigue and performance decline seen in all-out events lasting from about 30 seconds to 8 minutes, such as middle-distance swimming or an artistic swimming routine, and perhaps in team games in which there are repeated efforts of this nature.

There is a risk of gastrointestinal problems, and athletes should experiment in training.

Sodium citrate is another buffer but appears to be less effective.

More recently, chronic intake of β-alanine supplement over 4-10 weeks has been shown to increase levels of carnosine, an important buffer, in the muscles. There is some evidence that this might improve performance in some high intensity exercise models, but further work is required to be sure of the range of situations in which it might be useful.

In some events there may even be benefits from combining β-alanine supplementation (internal muscle buffer) and bicarbonate loading (external buffer in the blood) to maximise buffering potential.

Nitrate

In untrained and moderately fit individuals, a few days of supplementation of the diet with nitrate has been shown to reduce the amount of oxygen required to do a set amount of work. This improved efficiency might improve performance in events lasting a few minutes or longer.

Many vegetable foods are high in nitrate and beetroot juice has become a popular supplement with athletes. More research is needed to confirm the efficacy of beetroot juice/nitrate supplementation in well-trained aquatic athletes and to determine the events in which it might be useful.

Although there seems to be no problem with consuming additional nitrate in the form of vegetable intake, the safety of using nitrate powders is yet to be studied.

Supplements and doping

Athletes who are liable for drug testing under national or international programs should be especially cautious about supplement use.

Some supplements are prepared in unhygienic conditions and contain substance that can cause health issues. Others do not contain some or all of the ingredients - especially the expensive ones – that are listed on the label. Contamination of dietary supplements with substances that may cause an athlete to record an Anti-Doping Rule Violation is widespread – some surveys have suggested that as many as one in four supplements may result in a positive urine test. These prohibited compounds have not been declared on the label, so there is no way for the athlete to know that they are present. Purchases through the internet pose an even greater risk, and extreme caution should be taken. A sports nutrition expert should be consulted before taking any supplements.

At present, there can be no guarantee of the purity of any commercial supplement. The only way to be sure is to avoid supplements altogether, but many athletes are unwilling to accept this advice. The sensible athlete will want to see very good reasons for using a supplement and a very low risk of an adverse test before deciding to use it.

Many herbal supplements are claimed to increase testosterone levels and hence have an anabolic action. These include: Tribulis Terrestris; Chrysin; Indole-3-Carbinol; Saw Palmetto; Gamma-oryzanol; Yohimbine; Smilax; Mummio. All of these claims are based on studies in test tubes and none has been shown to work in humans. Athletes are cautioned against the use of these supplements.

Athletes must be aware of the strict liability principle that makes them responsible for everything they eat and drink. Ignorance is not an acceptable excuse for a positive doping result. Many international athletes, including some in aquatic disciplines, provide case studies of the misfortune associated with poor decisions regarding supplement use. Many have had to serve bans, prohibiting their participation in their sport for up to two years, due to an Anti-Doping Rule Violation associated with the use of a contaminated product.

Check all supplements with a medical officer or qualified sports nutrition professional. If there is any doubt at all, don't take it.

Issues to consider when deciding to use a sports food or supplement

- Is it safe?
- Is it legal?
- Is there evidence that it works?
- Am I aware of the correct protocols of how and when to take it?
- Can I afford it?

Changing Body Composition
Gaining Muscle - Losing Fat

Body mass and composition, including lean mass and fat mass, contribute to the success of athletic performance in most aquatic events.

Unfortunately, many athletes and their coaches have expectations that there is a single ideal physique for an event that can be achieved on demand.

In fact, optimal physique is individual to each athlete, and is the result of genetics and many years of conditioning via good eating and specialised training.

Even at the elite level, most aquatic athletes periodise their body composition over the year and may only need to be in top shape for the most important competitions. A regular program of body composition assessment can assess whether an athlete is making progress towards short term and long-term physique goals that will benefit performance as well as maintain health.

According to the resources available to a Sports Program, body composition can be assessed via a number of techniques including measurements of body dimensions and skinfold fat thickness, Multi-Current Bioelectrical Impedance (BIA) and Dual Energy X-ray Absorptiometry (DEXA). If such protocols are used, they should be undertaken by well-trained people who can achieve reliable measurements and provide suitable feedback. It is important that such assessments are made in a professional, non-threatening environment with the information being provided to athletes in a meaningful way:

- Athletes should be informed that the purpose of the assessment is to:
  - ✓ Monitor any potential unhealthy changes that may occur
  - ✓ Determine if exercise and eating strategies are having the desired impact
- Athletes should be assured that their results are confidential and will never be used to punish or embarrass them, or allowed to run comparisons or competitions with other athletes
- The information should be gathered privately, with only one athlete at a time, and not shared
- Results should be provided in terms of optimal ranges that are specific to the individual and with focus on changes between assessments (*"your muscle mass has increased since the last measurement"*)
- Results should be used to help explain changes in performance outcomes, and

to recommend or support changes in diet or training strategies

Athletes often have a desire to change their body composition to either reduce body fat stores or to support the gain of muscle mass.

This can be done by either altering energy intake, altering energy expenditure or both components.

In all cases where energy balance is changed to produce a loss of body mass and fat mass, case should be taken to preserve energy availability over the day and within the day so that healthy body function is preserved, and the goals of training can also be achieved. (see section on Energy availability)

Strategies for reducing body fat levels while sustaining lean body mass:

- Set realistic goals and timeline for fat/weight loss, preferably in the off-season
- Meet with a sports nutrition expert such as sports dietitian for an assessment and an individualized plan
- Try to create small energy deficits (no more than -400 kcal at any time during the day) by adjusting meal frequency and volume relative to energy expenditure
- Avoid skipping meals, since this can be counterproductive in terms of over-compensating later on by overeating and can actually result in undesirable changes in body composition, such as higher body fat, and loss of lean mass. It is preferable to have smaller more frequent meals than larger less frequent meals to improve body composition.
- Include protein-rich foods at all meals and snacks, spread evenly throughout the day
- Use well-chosen snacks between meals that fit within your energy budget
- Make meals filling and nutrient-dense by adding plenty of salads and vegetables, choosing wholegrain, unprocessed or low glycemic index forms of carbohydrate-rich foods
- Use low fat strategies when cooking or preparing meals
- Limit or avoid alcohol intake

Strategies for increasing energy intake to support growth or increase muscle mass:

- Set a pattern of frequent meals and snacks during the day
- Plan to have suitable foods and drinks with you wherever you go during the day that are portable and easy to consume
- Try to create small energy balance surpluses (no more than +400 kcal at any time during the day) by adjusting meal frequency and volume, relative to energy expenditure. This will help to support the larger muscle mass the athlete is hoping to acquire. Use a food record to help identify which times in the day could be used better for fuelling up
- Consume drinks that provide energy (juices, smoothies, liquid meal supplements, fortified milkshakes, flavored milk)
- Use opportunities before, during and after training to consume energy containing food and drinks.

Special Populations

Youth + Female Athletes

Young athletes

Aquatic sports can require a serious commitment from their participants at a young age.

For example, swimmers and divers can reach elite levels of performance in their early-mid teen years with many years of prior training supporting this effort. The implications of the commitment to daily training in young athletes include both the effect on energy and nutrient requirements, and the challenge of eating to achieve these requirements in a busy lifestyle.

The changing patterns of growth and development during childhood and early adulthood already raise special nutritional needs, while adolescence is a time of great social and psychological change which influences eating patterns and body image.

The needs of sport are superimposed on top of these features.

Various challenges can be faced both by the athlete and his/her family:

- the need for flexible household meal choices and timetables to suit the athlete's training schedule and nutritional needs
- the search for portable foods and drinks to accompany the young athlete on their daily schedule
- the struggle to find a balance between sports nutrition requirements and the social eating patterns of childhood (e.g. parties, holidays)
- managing the often chaotic features of the eating patterns associated adolescence and its growing self-determination
- coping with the change in body composition associated with puberty which may either substantially change energy/nutrient needs (e.g. the increased needs for growth and development in adolescent male athletes superimposed on high volume training) or create a conflict in terms of the ideal physique for performance (e.g. the gain in body fat in adolescent female athletes)
- the need to learn nutrition knowledge and practical skills at an early age to allow the young athlete to assume responsibility for intake during competition travel or to leave home for an enhanced training environment

The sections in Part 2 of this booklet outline the specific nutritional and lifestyle needs

associated with each of the aquatic disciplines.

The recommendations in these sections should gradually become integrated into the eating patterns of the young athlete as they increase their training load and undertake regular competition

Some special comments are provided:

- Children and adolescents can face periods of significant growth and development which increase their requirements for energy and nutrients such as protein, iron and calcium. Various sections of this booklet deal with the eating strategies that secure adequate intakes of these key building blocks.
- Children should develop lifelong good eating patterns and food knowledge via the family environment. From an early age they should be encouraged to join in family activities related to the choice, preparation and enjoyable consumption of wholesome foods. Sharing responsibility for the planning and organisation of food needs around training and competition will help them to gradually take responsibility for the special nutritional needs of an athletic career.
- It is particularly useful for children and adolescents to develop habits around choosing wholesome snacks. A pattern of frequent intake of nutrient-rich foods and drinks is well suited to support growing bodies and other scenarios of high-energy needs. In addition, it is useful to address sports nutrition needs by adding extra food opportunities before, during and/or after a training session or competition. This strategy not only helps to provide nutritional support where it is most valued, but can teach the young athlete to naturally adjust total energy intake up and down according to the exercise load.
- Adolescence can be a time of stress related to nutrition and body image unrelated to sport, and further exacerbated by the demands of high-level participation in sport. It is useful to provide education directed at the young athlete with positive messages about the role of sound eating practices in health, performance and enjoyment in life. Early detection and intervention around problem eating behaviours is encouraged.

Female athletes

Female athletes can face some additional dietary challenges, which include:

- Having additional requirements for some nutrients (e.g. iron)
- Having lower energy requirements (due to a lower body mass and muscle mass and often a lower total training load)
- Pressure to achieve unrealistic body mass and body fat levels
- Greater risk at developing disordered eating/eating disorders

The section in this booklet on energy availability explained the importance of providing adequate energy intake to meet the energy cost of training/competition.

Many female athletes are at risk of reducing energy availability, usually in an attempt to achieve unrealistic body composition goals, to levels that are not able to sustain healthy body function.

Some problems seen in athletes associated with low energy availability include:

- menstrual disturbances
- reduced basal metabolic rate
- compromised immunity
- poor hormonal function
- impaired bone density (this can mean irreversible loss of bone)
- impaired training adaptation leading to reduced performance

Early indications of low energy availability disordered eating or poor body image should be treated seriously, with athletes being referred to an appropriate expert for further assessment and help.

In particular, female athletes should treat an interruption or irregularity to a normal menstrual cycle as a warning sign. This is a problem that needs early assessment and intervention by a professional.

Nutrients of special concerns

Female athletes may be at risk of poor iron status because of increased iron requirements due to menstrual blood loses. They may also tend to restrict energy intake and limit certain foods, which can result in low iron intake.

An adequate calcium intake is also important for female athletes and may be compromised by inadequate energy intake or fat diets. Poor dietary calcium intake may exacerbate bone health problems associated with low energy availability.

See other sections of this booklet on Iron- and calcium- rich eating, and note that females must generally focus more carefully on these nutrients since they must meet their requirements from a smaller energy intake.

Part 2 Aquatic Discipline Specific Nutrition

Swimming

Committed swimmers usually train 2-6 hours each day, often combining two sessions in the pool with an additional land-based workout (e.g. resistance training, core training or running).

Contemporary nutritional strategies should be incorporated in the training program of swimmers to support such activity.

Competition formats span single day meets up to the 8-day format on the Olympic and World Championship programs. Highly talented swimmers may compete in a range of strokes and distances in a single meet, with heats, semis and finals often being swum to determine the eventual winner of the most prestigious programs.

Although muscle fuel stores are not challenged by a single event (with the longest event of 1500 m being completed in ~ 14-17 min at elite level), recovery between swims is important for the competitor who faces a busy race program with several races in a single session.

Training issues

Matching energy needs to support training and maintain/achieve optimal physique

Energy and carbohydrate needs vary according to the annual program, macro cycle, training week, training session and stage of development.

- Energy needs are increased during growth, in heavy training periods and during training at high altitude. To avoid compromised training and an increased risk of illness in these settings, swimmers are recommended to follow eating strategies to match increased energy and carbohydrate intake to their increased needs. Tactics, also covered in other sections of this booklet include:
  - ✓ Increasing the number of meals and snacks in the day
  - ✓ Adding carbohydrate-rich snacks and fluids (juice, sports drink, flavored milk, smoothies, liquid meals) around training sessions
- During periods of reduced training load (e.g. taper and injury) energy intake should be adjusted to avoid unnecessary gain of body fat. Strategies to match lower energy requirements include:
  - ✓ Reducing intake of energy dense low-nutrient snacks

- ✓ Focusing on foods high in volume and fiber (e.g. vegetables, fruits) and low-fat versions of protein-rich foods (e.g. low fat dairy, filets of fish/chicken)
- ✓ Avoiding *"eating to boredom"* during sudden increase in leisure time

- A busy training schedule requires an eating plan rather than an ad hoc approach to nutrition. This plan should be underpinned by knowledge of food composition, and forethought to ensure that there is easy access to appropriate snacks in an "on the run" lifestyle
- Rapid body weight changes are discouraged. Swimmers should aim for modest improvements in dietary choices to achieve ideal physique over a period of time. Adequate energy availability is important for health and performance (see section at front of booklet)

Manipulating carbohydrate availability

Daily carbohydrate intake should reflect the metabolic needs of the muscle and/or the goal of the training. This may range from 3 - 10 g/kg/day according to the type and volume of training (see Carbohydrate needs for training).

Meeting the muscle's carbohydrate needs (=high carbohydrate availability) will enhance recovery, delay fatigue and improve performance.

Meanwhile occasional manipulations to achieve low carbohydrate availability around selected training sessions (≤ 1-2 session per week) may further enhance metabolic adaptation.

- *Strategies to achieve high carbohydrate availability:* Adding carbohydrate rich foods and snacks (e.g. rolls, cereal, muesli, juice, dried fruit, sports drink, sports bar, and gel) around key sessions (pre, during, post) will permit high intensity training and reduce exercise induced stress on the immune system
- *Strategies to achieve low carbohydrate availability:* Training first thing in the morning prior to eating carbohydrate is an easy way to undertake a workout with low carbohydrate availability and is commonly undertaken by swimmers without recognition of the tactic. Scientists are still investigating the pros and cons of deliberately undertaking sessions with low carbohydrate availability to promote training adaptations since the application of this strategy requires planning to periodise it to the right type of training sessions and to avoid any potential negative outcome (e.g. compromised immune function, overtraining)

Fluids and fuel during training

- Swimmers who train indoors in temperate water at low intensity have modest sweat losses (~0.3-0.5 L h^{-1}) which may be addressed by drinking to thirst. Workouts undertaken with higher intensity, in warm outdoor pools or involving land based activities incur greater fluid needs which may require an organized approach
- Carbohydrate intake during training should reflect the fuel needs and performance goals of the session
- Easy swim session < 90 min: water is usually appropriate and should be consumed in amounts that limit dehydration (< 2% of body weight)
- High intensity sessions with high carbohydrate availability: sports drink and/or gel providing 30 - 60g CHO h^{-1} and fluids according to individual sweat rate
- Sessions targeting low carbohydrate availability sessions: consume water to limit dehydration (< 2 % of body weight), consider mouthwash/candy in oral cavity

to address fatigue without needing to ingest a fuel source

Recovery

Recovery strategies should be adjusted to the swimmer's individual needs based on 1) the physiological stress achieved by the first exercise bout 2) the period of recovery 3) the goals of the next workout 4) the swimmer's energy budget and need to manipulate physique.

- Swimmers should aim to consume carbohydrate (~1g/kg) immediately after key workouts when recovery time is limited (<8 h) and the following session is glycogen dependent
- Swimmers should consume foods providing a modest serve of high-quality protein (~20-25 g or 0.3 g/kg protein) soon after key pool sessions and resistance training. Similar protein serves should be spread regularly over the day in meals and snacks.
- Less demanding training sessions or sessions with longer recovery periods may not need such aggressive recovery routines. In these situations, or when the swimmer's energy budget is restricted, the normal meal routine may be used to achieve recovery goals.
- While sports foods may provide practical recovery snacks, many whole foods are also suitable (e.g. muesli with milk/yoghurt, sandwich with egg/meat filling, flavored milk). Choices can be made based on food availability, practicality, expense and individual preference.

Competition issues

- Swimmers should recognise that their energy requirements are lower during the pre-competition taper due to the decreased training volume. Nevertheless, high-intensity sessions are retained during this period and are highly glycogen dependent, requiring adequate carbohydrate availability.
- A single race in the pool will not stress the fuel stores, but swimmers competing in several races over a session or meet should have a recovery plan similar to that used in training.
- For whole day meets, swimmers should bring a suitable supply of carbohydrate-rich foods to the poolside. Easily digestible snacks and sports products can be consumed when there is < 60 min between races while nutritious whole

foods (e.g. sandwich with egg/meat/cheese filling, cereal and yoghurt, pasta salad, fruit) are recommended during longer breaks

- Swimmers should adopt a race-day snack and fluid plan according to their real needs, avoiding over consumption due to an over-eager approach as well as inadequate intake due to poor preparation
- In championship meets, the usual routine is to consume a substantial lunch after the morning session (heats) and a light carbohydrate-rich snack before returning to the pool for the evening session (finals)

Performance enhancing supplements

There are a few supplements that may be beneficial for swimming performance when correctly applied – these include sodium bicarbonate, creatine, caffeine and possibly beta alanine and nitrate (see dietary supplements section).

These supplements may be appropriate for highly trained swimmers under the supervision of experienced sports nutrition/science professionals.

Artistic Swimming

Artistic Swimming is unique among aquatic sports, combining speed, power and endurance with precise synchronized movements and high-risk acrobatic manoeuvres.

Athletes spend a great amount of time upside down, underwater and undertaking exercise while breath-holding.

The nutritional demands of the Artistic swimming athlete are complex due to the intense training demands and aesthetic nature of the sport. Several special challenges are faced by Artistic swimmers:

- The nature of training favours lengthy sessions in a variety of exercise modalities with limited breaks. Such a structure makes it difficult to consume adequate energy and fluid during the session. Furthermore, the underwater and upsidedown manoeuvres may cause discomfort following food/drink intake

Artistic swimming is an aesthetically judged sport—making appearance and body composition a prime focus for coaches and athletes. Individuals are required to achieve a uniform 'ideal' shape to achieve competition success.

Training issues

Artistic swimmers should aim for a well-chosen diet that is adequate in energy, carbohydrate and protein to optimize training and performance.

Achieving an ideal physique and adequate energy availability

The overzealous restriction of energy intake to achieve weight loss goals can sacrifice bone health, performance, menstrual function and other health issues.

The artistic swimmer should achieve her physique goals according to a safe and well-organised plan.

Tactics include:

- Choosing a safe and healthy body composition goal, with adequate time to achieve this
- Consulting a sports nutrition expert to help with meeting dietary requirements and managing body composition issues
- Ensuring that physique changes are achieved while maintaining adequate energy availability (see section on energy availability)
- Considering the timing of meals and snacks to optimise energy availability over the day and promoting optimal nutrient support for training sessions
- Seeking early intervention at the first sign of food related stress

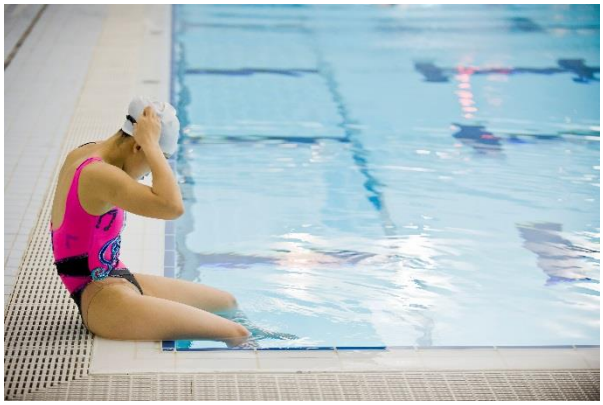
Carbohydrate: a key nutrient for training support

The Artistic swimmer should vary their carbohydrate intake according to the fuel needs of training (volume/intensity/goal). The section on carbohydrate needs for training provides a summary of the periodisation of daily intake, and specific intake around training sessions.

Protein: Important for building and repairing muscle

The timing, quantity and choice of protein-rich foods is important to meet daily protein needs and to support the adaptation to training.

Artistic swimmers should plan their meals and snacks to provide a regular spread of high-quality protein choices over the day, including in the recovery after key workouts. (See section on Protein needs)



Eating for comfort and nutritional support during training sessions

Since a large percentage of training is done upside down in the water, artistic swimmers can experience gastrointestinal upset. To relieve symptoms, the athlete should experiment with various strategies within their everyday eating plans:

- Avoid eating large volumes of food before training sessions
- Avoid excess intake of high fiber foods
- Avoid other gas-producing foods, such as cruciferous vegetables, peppers and onions

Coaches should allow sufficient breaks during workouts to support adequate fueling and hydration. Sections in this booklet provide strategies for fluid intake and carbohydrate to meet the needs of training sessions.

Diving

Modern day competitive diving involves grace, power, balance, and flexibility, all of which requires years of intensive training to achieve.

Due to the biomechanics of this acrobatic and aesthetic sport, the diver must be short, well-muscled and lean. As the increasing difficulty of dives has increased the physical and mental demands of the sport, divers and coaches have become more interested in strategies that can support high level training and conditioning.

Nutrition is important to support skill and concentration during long practices, to promote adaptation and reduce the risk of illness and injury, and to allow the diver to compete in peak shape.

A multi-disciplinary sports medicine team should be integral to the daily training environment and suitable foods and fluids should always be available during prolonged practices and competitions.

Training issues

Ideal physique

Pressure is placed on divers to achieve, through manipulation of weight and body composition, a physique that is consistent with competitive expectations. As the difficulty of the competition dive increases, lean muscle mass and consistent power become even more important. This emphasis on weight, performance and appearance is engrained from a young age as athletes strive to attain a high lean-to-fat ratio, with the goal of achieving a highly toned and contoured physique.

Thus, nutritional intake and the science behind it can very much help to lead to medal performances. That does not mean however that the days of disordered eating and eating disorders in diving are gone. The detrimental consequences of restrictive eating and low energy availability are well known (see section on Low energy availability)

Energy and macronutrients

While divers typically train for at least 5 hours each day, specific knowledge of the training and competition demands is essential to interpret current carbohydrate intake guidelines. Although we have no definitive assessment of carbohydrate use during diving training, daily requirements are likely to be within 3-8 g/kg body mass/day, with the higher values accommodating growth and development in younger divers (see section on Carbohydrate needs for training).

Divers do not need to practice carbohydrate loading strategies that maximize glycogen stores; indeed, over-storage in the muscle could compromise flexibility.

Since total energy intake may need to be carefully managed to meet physique goals, the focus of the training diet should be on nutrient-dense carboydrate-rich foods. The exception to this may be around lengthy training sessions where more practical forms of carbohydrate are useful to maintain muscle and brain supplies. Since blood sugar fluxes in 3-hour units, the pre-training meal should be followed with foods and beverages that can sustain normal blood sugar over the duration of the session.

Total daily protein intake that optimises daily diving training and promotes recovery following exercise is approximately 1.2 to 1.7 g/kg body mass, depending on protein quality and eating frequency. Recommended protein intake can generally be met through diet alone, although the use of protein drinks (i.e. whey protein isolate) and related packaged foods may assist in the timely intake of protein immediately following training or competition.

Slightly higher protein intakes may be required for athletes striving to lose (fat) weight so as to better maintain lean muscle mass. Ideally, the diver should maintain energy balance and a regular meal pattern, providing 20-30 grams/meal of high-quality protein to maintain and/or increase muscle mass and bone density. The section on protein intake helps to identify protein-rich foods that can be included in meals, as well as snack choices that also contain carbohydrate to assist with post-training recovery.

Fat is a source of energy, fat-soluble vitamins, and the essential fatty acids. While high-fat diets are not recommended for athletes, extreme restriction of fat intake is also unwise.

Micronutrient Supplementation

To ensure sufficient intake of micronutrients (i.e., vitamins and minerals), divers are encouraged to consume nutrient dense foods. Studies assessing the diets of adolescent female athletes in aesthetic sport suggest they are at high risk of consuming inadequate amounts of macro and micronutrients in an attempt to achieve or maintain the ideal body size and *'thinness'* that is perceived to be associated with success.

Calcium, zinc and iron are micronutrients that vegetarians may lack. Vegetarian athletes should ensure that their regular foods contain adequate amounts of these micronutrients.

Focusing on nutrient-rich wholefoods to meet energy needs should provide adequate intake of micronutrients, and alleviate the need for supplements.

Hydration during training

Divers should consume sufficient fluids before, during, and after exercise to sustain health and performance.

Dehydration, defined as a body water deficit in excess of 2–3% body mass, decreases exercise performance in laboratory settings, and even a small threat to concentration and skills can have large consequences in a sport such as diving.

Of course, overhydration, leading to a weight gain can also be a problem. The section on fluid balance in this booklet provides guidance on the assessment of sweat losses and the success of hydration strategies.

Competition nutrition

The pre-event meal provides an opportunity to fine-tune carbohydrate and fluid levels, as well as to leave the diver with a feeling of comfort and confidence. The diver should experiment to find their own ideal routine.

During a competition session, the diver should continue with fluid and fuel intake strategies that have been successfully developed during training.

Water Polo

Water polo is the only team sport sanctioned by World Aquatics. Like most team sports, water polo is characterized by a high intensity, intermittent activity pattern coupled with aggressive physical contact with opposing players.

Water polo players require endurance, strength, power, swimming speed, agility, tactical awareness, and specific technical skills, including ball control.

Physical characteristics of water polo players

Water polo players are typically heavier and have higher body fat levels than other aquatic athletes. Physical characteristics are also observed to differ across positions, with center players being heavier and having higher body fat levels than perimeter players. This difference is likely to offer an advantage to the center player, since they are required to hold position close to goal while grappling and wrestling aggressively with opposition players. In contrast, perimeter players need to have speed and agility.

Unlike male water polo players, it is difficult for female players to maintain and or achieve a high body mass without increasing their body fat levels. This is a challenging issue to manage given societal pressures for women to achieve a light and lean physique. The issue requires a delicate approach involving input from coaching staff, strength and conditioning specialists and sports psychologists as well as appropriate nutrition advice. This multi-disciplinary approach will help the player to realize the performance benefits of an intervention to increase body mass as well as to have the necessary knowledge and practice to achieve it.

Daily training nutrition requirements

A water polo player's daily carbohydrate intake should be modified throughout the training year and strategically coordinated with daily training sessions to support training performance and recovery. Although we have no definitive assessment of carbohydrate usage during water polo training and competition, it is likely that daily requirements are within 4–8 g/d (see carbohydrate needs for training section of this booklet). Higher intakes may be required for a younger player to accommodate growth and development, a leaner athlete with high daily energy requirements, or the athlete striving to gain lean muscle mass. The lower range recommendations for carbohydrate intake are more suited to an athlete with high body fat levels (given that recommendations are expressed relative to body mass), an athlete returning from injury or on a break where training loads are

reduced, or a female player striving to reduce body fat levels.

Training routines during the pre-season and pre-competition phases, when it is commonplace to undertake two or three sessions a day, will require more aggressive daily fueling strategies. In these situations, it is even more important for the player to be organised to ensure they have a range of nutritious snacks on hand to support training performance and initiate recovery after training.

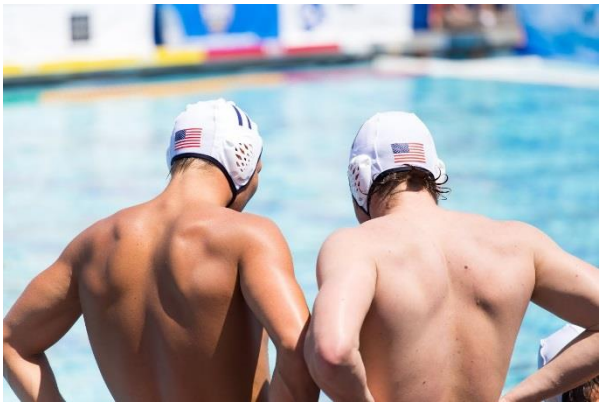
As high body mass appears to offer a physical advantage in water polo, it is important to consider strategies that promote lean muscle gains. This is particularly relevant to a younger player aiming to transition into elite level competition. Strength and conditioning workouts form a routine part of weekly training and in some instances will be included throughout the annual training and competition calendar. Current evidence indicates that 20–30 g of protein consumed immediately after a workout optimizes muscle protein synthesis.

Competition issues for Water Polo athletes

Although it is not clear that carbohydrate-loading will benefit water polo performance, a player should commence match day with normalized or elevated muscle glycogen stores. This is particularly important in tournament settings where several games are played over a weekend. A bench player or reserve goalkeeper who has little game time on match day should complete additional training as their dietary habits are likely to mirror those of starting players.

Pregame meals are highly individual and will be heavily influenced by the scheduled game time. The player should include familiar, easily consumed carbohydrate foods and fluids in this meal. Liquid meal supplements provide a suitable alternative for the nervous athlete with a reduced appetite. For afternoon or early evening games, the player should maintain their typical daytime meal pattern throughout the day, rather than sleep in and miss meals.

During the match, the player should consume carbohydrates in the form of sports drink or carbohydrate gels. Only small amounts of carbohydrate are needed since typical workloads are unlikely to stress muscle glycogen stores, and the benefits are most likely to be achieved via stimulation of the brain and central nervous system. Some consideration should be made regarding this advice for adolescent athletes given the dental concerns associated with the intake of sugary drinks.



Although games at major international competitions are typically scheduled 48 hours apart, younger players may be involved in round-robin tournaments in which they are expected to play several games over a weekend. A well-organized, portable team recovery station, which may include sports drinks, liquid meal supplements (i.e., milk or soy-derived supplements), cereal bars, fruit, dried fruit and nut mixes, sports bars, and flavored milks will facilitate post-game recovery.

Muscle refueling can be delayed by contact injuries and excessive postgame alcohol intake. In the latter case, postgame celebrations will further hamper recovery due to the disruption to sleep and rest, as well as failure to follow other guidelines for eating. Perhaps a more significant issue relates to player safety and misconduct

when team athletes engage in excessive postgame celebrations.

Nutrition obstacles on the road

Tournament guidelines generally expect the host country to arrange all ground transport and accommodation needs for traveling water polo teams, including food needs. Visiting teams need to plan ahead to ensure that food items that are important in their everyday eating practices are available within catering plans, and that athletes with specific dietary requirements can meet their needs.

Eating among other athletes and under the watchful eye of coaches and support staff in unfamiliar environments can be stressful and confusing for some touring players. It is not unusual for athlete's dietary intake to be influenced by a pack mentality that may not align with their unique individual dietary requirements. The senior leadership group within the team can have a significant bearing on the dietary habits of other team members and the culture developed around food, including alcohol.

Further strategies for eating on the road are summarised in *Part 3* of this booklet.

Dietary Supplements

Although there are few specific studies on the effect of ergogenic supplements on water polo play, products that have the potential to offer a performance advantage to the activity patterns observed in match play and training sessions include bicarbonate, beta alanine, caffeine, and creatine.

Of course, such supplementation practices are appropriate only for high level players and should be undertaken with appropriate supervision and with the goal of devising protocols that are tailored to the individual player and situation.

Open Water Swimming

Open water swimmers train mostly in the pool with additional sessions in rivers, lakes and the ocean to acclimatize to a race environment.

Although the training volume of open water swimmers is similar to swimmers competing in the longest pool events (800 m, 1500 m), race distances in open water swimming are significantly longer (5 km, 10 km, 25 km in FINA events) and require specific nutritional strategies for optimal performance.

Training issues

Strategies recommended for pool swimming, particularly those practiced by distance swimmers are suited to open water swimmers.

Energy and carbohydrate needs will vary over the training program and should be periodized accordingly (see sections on energy availability and carbohydrate needs of training.

During periods of higher energy requirements, such as an intensive training camp, increased energy intake can be achieved by tactics including

- Having an increased number of meals/snacks per day
- ensuring access to compact carbohydrate rich snacks (e.g. rolls with jam/honey, dried fruits, biscuits, sports bars, sweet dairy products, juice)
- adding oils and nuts to meals
- consuming high-energy fluids including milk drinks, juice and liquid meal supplements

Protein is important also for training adaptation, and is achieved by the good timing of intake of high quality protein (~ 20-25 g) regularly throughout the day. Examples of such foods can be found in the section on Protein.

Fluid intake during training should be adjusted according to the swimmer's individual sweat rates and environmental factors, particularly water and ambient temperature.

During training, the fluid may contain carbohydrate similar to recommendations for pool swimmers (30-60 g per hour), while race specific practice for longer events may require greater intake (up to 90 g/h from multiple transportable carbohydrate sources). Race nutrition strategies should be well-tested in training.

Competition issues

Differences in the duration of races and environmental conditions call for a variety of fluid and fueling strategies. A cost-benefit analysis should be used when selecting

fueling strategies that match different race scenarios. For example, the swimmer might evaluate the benefit of swimming past a feeding pontoon in order to maintain the line of least distance versus the expense of losing an opportunity for hydration and fueling. A combination of self-carried supplies (e.g. carbohydrate gels tucked into the swimming costume) and those at feeding pontoons can be used to achieve carbohydrate intakes according to race fueling targets while supporting good race tactics.

Pre-race nutrition strategies

- For races of 10 km or longer, an open water swimmers should carbohydrate load by consuming a high carbohydrate intake (10 g/kg/d) during the last 24-36 hours. This will optimise pre-race muscle glycogen stores to support a higher race pace, especially in the last stages of the race. Female open water swimmers should make sure that their energy intake is also sufficient to support glycogen loading
- The pre-race meal (1-4 h prior to race) should continue to supply carbohydrate (1-4 g/kg) from foods that are easy to digest and familiar to the athlete. In most cases, this will be a breakfast meal, where popular choices include oatmeal, muesli, rolls, juice, yoghurt and additional sports products to further increase the carbohydrate content of the meal
- When there is the potential for large sweat losses to lead to substantial fluid deficits during the race (e.g. high water temperatures and limited opportunities for fluid intake), some swimmers may consider pre race hyperhydration strategies. The intake of a salty beverage in the hours before the race (e.g. 10ml kg^{-1} of a 165 mmol/L sodium drink) will increase body fluid stores since the salt content temporarily increases fluid retention rather than urine production
- The intake of similar amounts of icy beverages (e.g. 500 ml of a slushie) around 30 minutes before a race can pre-cool the swimmer and assist with temperature regulation during longer races swum in hot (e.g. 30°c) water

Nutrition strategies during competition

Fueling

- ≤ 5 km races: The need for nutritional support during short races is minimal but swimmers may benefit from the mouth-brain carbohydrate connection which has been shown to enhance performance in cycling/running protocols. The most practical way to achieve this is probably to tuck a piece of candy into the mouth (e.g. cheeks)
- ≥10 km races: Swimmers should consume carbohydrate at rates of up to 60-90 g per hour to provide an additional source of muscle fuel. Carbohydrate choices include sports drink, gels, sports confectionary, or foods according to race practicality and swimmer preference. The absorption of carbohydrate at the highest rates of intake is aided by use of products containing mixtures of maltodextrin/glucose and fructose (*"multiple transportable carbohydrates"*). It is essential that such feeding is practiced in training before racing to improve gut tolerance and fine-tune a personalized plan. Feeding techniques should also be practiced to develop the skills that avoid spill of fluid/fuel and loss of time. Swimmers are encouraged to use the feeding pontoons and to consider carrying some of their own-supplies to allow for good race tactics
- ≥ 25 km races: A wider range of salty and sweat foods/sports products might help the swimmer consume adequate amounts of energy, carbohydrate (up to 90 g/h), protein and sodium during long races where flavor fatigue may become an issue

Hydration

Though fluid needs of swimmers are lower than land based athletes, sweat rates can easily triple as water temperature increases (e.g. from 24°c to above 30°c, sweat rates may increase from ~0.4 L to 1.2 L h^{-1}).

Open water swimmers are recommended to establish hydration strategies that limit dehydration to 2 % of body weight, using information presented earlier in this booklet.

- It may be useful to include sodium in fluid and food choices consumed during races, according to sweat sodium losses (sweat rate and composition of the individual swimmer and race environment). During longer races, electrolyte containing sports bars, gels and foods may be used in addition to sports drink
- Open water swimmers might want to manipulate the temperature of the fluid ingested during a race to attenuate core temperature changes and improve palatability (warm drinks in cold environment and cold drinks in hot environment)

Recovery

Open water swimmers who compete in several distances in one meet should pay careful attention to recovery routines. Each of the World Aquatics Open Water Swimming distances will stress glycogen stores, thus proactive refueling is required for fast recovery. Swimmers should aim to get a head start on refueling by consuming carbohydrate (1 g/kg) soon after the first race. Consumption of 20-25 g of high-quality protein and a blend of nutritious antioxidant rich foods in the following meals is also recommended.

Performance enhancing supplements

Caffeine ingestion before and/or during an open water race can enhance central drive while loading with buffering agents (beta alanine and sodium bicarbonate) might help fight the acidic environment in the final sprint to finish line. Correct protocols for performance enhancing supplements should be trialed only in the supervision of a trained professional.

Part 3 Eating Strategies

Eating while travelling

High-level athletes in aquatic sports can face demanding training and competition schedules featuring extensive travel. For example, depending on the event, age and season, the elite swimmer may have between 30 to 100 races per year. Such a schedule will involve crossing multiple time zones in varying countries all with differing environmental, cultural, food and fluid choices. Frequent changes in location and the required travel demands create a number of potential challenges:

- Interruptions to normal training and lifestyle routine while traveling and recovering from travel
- Travel fatigue - physiological and psychological factors that build up during a single trip or accumulate throughout the season
- Jetlag - symptoms due to the time-phase shift to a new time zone
- Changes in environment (climate or altitude) requiring change to nutrition & hydration needs
- Differences in language and food culture which can result in inappropriate food choices including inadvertent exposure to food allergens and intolerances
- Varying catering arrangements with altered access to normal food choices or eating times
- Buffet style dining which may be associated with over-eating
- Different standards of food and water hygiene, including the water in which open water events are conducted

These challenges can be addressed with a variety of strategies.

Planning ahead

- 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.

Supplies to supplement local food

- A supply of portable and non-perishable foods should be taken or sent to the destination to replace important items that might be missed.
  - ✓ The athlete should consider what is available in the new location versus the weight/convenience of traveling with extra food

- ✓ They should also check with the local country's customs and quarantine to see what foods are permitted to be brought into the country of travel

- The athlete should be aware that many catering plans only cover meals. Since the athlete's nutrition goals are likely to include well-timed and well-chosen snacks and recovery nutrition, supplies should be taken to supplement meals en route, at the destination, and around competition.

Examples of suitable travel foods

- ✓ breakfast cereal and cereal bars
- ✓ powdered milk and liquid meals
- ✓ sports drinks and protein powders
- ✓ juice concentrates
- ✓ dried fruit and nuts
- ✓ Crackers and nut butters
- ✓ Freeze-dried and canned meals.

Eating and drinking well en route

- The athlete should be aware of the risk of "*boredom eating*" when confined in a travel vehicle. Extra vigilance is needed to ensure that they eat according to their real needs, taking into account the forced rest while travelling

- When moving to a new time zone, the athlete should adopt eating patterns that suit their destination as soon as the trip starts. This will help the body clock to adapt

- 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

  - ✓ Fluid choices should be appropriate to the athlete's energy requirements

  - ✓ Contrary to popular beliefs, caffeinated drinks such as tea, coffee and cola beverages have minimal effect on hydration and may even supply a substantial amount of fluid to the diets of habitual consumers. However, the intake of caffeine should be considered in view of sleep patterns

Care with food/water hygiene

- A fundamental item of information to source is whether the local water supply is safe to drink. When this is not the case, the athlete should stick to beverages presented in sealed bottles from recognised manufacturers or to hot drinks made from well-boiled water

- Ice should be avoided in environments with unsafe water supplies since it is usually made from tap water

- In high-risk environments, the athlete should eat only at good hotels or well-known restaurants or from the athlete's village cafeteria. Food from local stalls and markets should be avoided, however tempting it is to have an "*authentic cultural experience*"

- The safest foods are those which have been well-cooked and served shortly after preparation.
- It is best to avoid salads or unpeeled fruit that has been in contact with local water or soil

Adhering to a food plan

- The athlete should choose the best of the local cuisine to meet their nutritional needs, supplementing with their own supplies where needed
- The athlete may even experiment with foreign cuisines and local dishes prior to undertaking their travel to become more accustomed to the food they are likely to encounter
- The athlete should be aware that their training and race/event schedules (e.g. pool time) may overlap with meal times, especially in countries with a different culture of eating patterns or in locations where 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
- The athlete should be assertive in asking for what they need at catering outlets – e.g. low fat cooking styles or an extra carbohydrate choice
- 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 their individualized, and optimal, meal plan

Challenging Environments

(Hot & Cold Water, Altitude & Pollution)

Aquatic athletes, especially open-water swimmers (OWS), can be challenged by difficult and changing environmental conditions.

Environmental challenges include:

1) impaired temperature regulation in hot or cold water and air;
2) altitude; and
3) environmental pollution.

Such challenges can add significant undesired stress that may compromise an athlete's energy balance, recovery, immune function, optimal training adaptation and ultimately performance. There are a variety of different strategies to address these challenges.

Varying water temperatures – effects on performance and safety

World Aquatics rules state that water temperature for open water events must be between 16°c to 31°c, with some races lasting 2 to 5 hours.

Human body thermal conductivity is approximately 25-times greater in the water than air, so water that is even marginally colder than body temperature (~37°c) is a significant *"heat sink"* and has the potential to cause hypothermia (decreased body temp).

Hypothermic events happen more frequently during Open Water events and are more of a concern than hyperthermia – but both are equally detrimental to performance and health.

Some interventions to consider in warm or cold water include:

- A swimmer's inherent body fat may be the most important safeguarded against hypothermic responses, and may be chronically manipulated by a combination of energy intake and expenditure.
- Alternatively, a high body fat level can limit an athlete's ability to dissipate heat in warm water conditions and place them at a higher risk for heat-stress or heat stroke.
- Athletes should be screened for pre-existing viral illness, as there is some evidence that heat-stress/warm water conditions may predispose athletes to a higher risk for a cardiomyopathy.
- Optimal pre-race fueling (glycogen stores) and in-race carbohydrate and fluid intake appears to combat shivering and the preferential glycogen utilization when an athlete is cold/shivering

Altitude

Altitude training is a common tool used by swimmers to prepare for international competitions.

Although the use of altitude training has been explored for 40 years there are few controlled studies of altitude training on top level swimmers, let alone studies investigating the impact of nutrition and altitude training.

The possible positive effects of altitude include:

- Hypoxic stimulus to increase erythropoietin which, under ideal conditions, can increase red blood cells and oxygen carrying capacity (oxygen delivery)
- Non-haematological benefits (e.g. increased muscle buffering and exercise economy/efficiency)
- Motivating and invigorating training environment

Nevertheless, the following challenges of altitude training must be recognized:

- Decreased training velocities and biomechanical specificity of training
- Increased energy expenditures/appetite suppression, which causes increased risk for energy deficits and weight loss
- Decreased recovery profile and immune system function
- Increased risk for acute and chronic dehydration

Recommendations, based partially on evidence and some anecdotal observations, to maximise the benefits of such training include the following strategies:

- Iron screening should occur well before altitude. When pre-altitude serum ferritin concentrations are <30µg/L for females or <40µg/L for males, decisions to undertake an altitude intervention should be reconsidered or delayed
- Athletes going to altitude should increase dietary intake of iron or undertaken iron supplementation with advice from qualified sports medicine professionals
- A proactive approach to hydration should be implemented in view of increases in sweat rates and other forms of fluid loss
- Increased monitoring of sleep, hydration, body weight, fatigue and recovery should be implemented to catch early warning signs of poor adaptation
- Other nutritional interventions that may be required include increased intake of energy, carbohydrate, and natural antioxidants (fruits and veggies)
- Ideally, high-intensity training sessions should be conducted at sea-level, or lower altitudes, and will require longer interval set breaks and rests within workouts

Air and water pollution

There is very little research on the impact of air and water pollution on athlete health and performance. However, some aquatic athletes experience periodic respiratory issues related to chlorination of pool water and poor air quality, with up to 74% of elite swimmers reporting respiratory symptoms throughout a training season.

Since air and/or water pollution may cause an impairment of the immune system, nutrition interventions that support the immune system may be beneficial.

These include:

- Adequate carbohydrate intake during and after training
- Adequate energy availablity
- Increased natural antioxidant intake (fruits and vegetables)

- Possible probiotic support

Practical recommendations to minimize adverse effects of water pollution during open water races 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.

Part 4 Resources

Consensus Statement on Nutrition for the Aquatic Sports

An effective nutrition planis critical to success in all aquatic sport disciplines for athletes at every stage of their development. A well-designed, periodised training program remains the fundamental cornerstone of peak performance outcomes, but this will mean little if nutrition needs are ignored. Specialised sports nutrition experts should apply evidence-based science to the intake of key macro- and micro-nutrients essential to the health, physique and performance of all athletes. Coaches, parents and health professionals in the athlete support team should recognise that these needs are specific to the individual and are different for each of the aquatic disciplines. The needs of athletes also vary through maturation and during periods of high energy expenditure, the taper, competition and post-competition recovery.

Strategic intake of foods and fluids can enhance performance in training and competition and help athletes to realise their potential. Specific nutrition strategies should match the phase and type of training, including concurrent endurance and resistance training, altitude, overload and taper. When the training load changes during high volume phases, injury, taper, or in the off-season and after retirement, athletes should adjust their energy intake according to the altered energy expenditure. Recovery after training or competition should address the nutritional aspects of restoration of homeostasis, adaptation to the exercise stimulus and preparation for optimal performance in the next session. These challenges are specific to the session and the athlete's goals and may require a planned intake of key nutrients such as protein, carbohydrate, fluid and electrolytes, particularly in the period immediately after training. Training adaptations can be promoted by the ingestion of about 0.3 g/kg body mass of high-quality protein at intervals throughout the day and around training sessions, up to a total of about 1.5 to 1.8 g/kg body mass per day. Carbohydrate intake, both over the day and in relation to training sessions, should be manipulated according to the fuel costs of training and racing, and the varying importance of undertaking these sessions with high carbohydrate availability.

Informed management of body mass and composition is key to ensuring that athletes achieve peak performance, including the meeting of aesthetic expectations. Low energy availability (EA) and disordered eating are concerns for athletes in disciplines that emphasise leanness, such as artistic swimming, diving and swimming. Athletes in all aquatic sports should practise healthy eating behaviours to prevent low EA and reduce the risk of suppression of the endocrine, metabolic and immune systems that can lead to impaired bone health and injury. Even when a well-constructed and justified program to reduce body fat is undertaken, adequate EA should be ensured. The athlete's support team should be educated to recognise early signs and symptoms of low EA and disordered eating behaviours.

Aquatic athletes are encouraged to consume a well-chosen diet with sufficient energy, macronutrients (particularly carbohydrate and protein), and micronutrients, to maintain immune function and health. Vitamin D status may be compromised in athletes who are predominantly based indoors. Bone health requires adequate energy availability and micronutrient intake: bone-loading activities, which may be limited in an aquatic sport

training program, are also required. Strategies to manage alcohol intake should be developed in the context of the team culture to minimise the negative consequences on recovery and athlete welfare.

The use of supplements does not compensate for poor food choices. Supplements containing essential nutrients may be useful only when a diagnosed deficiency cannot be corrected easily and promptly by changes to the diet. Athletes contemplating the use of supplements and sports foods should consider their legality, efficacy, cost, practicality, and safety, including the risk to health and performance. Contaminated supplements may cause a positive doping test. A few evidence-based supplements may provide a performance benefit for some athletes with no risk to health, but the scientific evidence specific to aquatic sports is often limited or absent. Ingesting carbohydrate via sports drinks, gels or sports foods during intensive and/or prolonged training sessions should be beneficial for performance.

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 jetlag/travel fatigue. Nutrition interventions that might mitigate the negative environmental effects include: adequate hydration, carbohydrate, protein and iron intake while at altitude; manipulation of fluid and carbohydrate intake during races according to the varying water and ambient temperatures; and careful food and fluid hygiene practices when travelling.

Nutrition support in elite sport should be provided by qualified professionals and nutrition assessments should be a key element of the periodic health examination. Proactive nutrition screening can allow early detection and resolution of developing nutrition-related issues. Research into nutrition and aquatic sports is underdeveloped: much remains unknown, but some sound principles have been established. Education of the athlete support team, including coaches, healthcare providers, parents, and athletes themselves is a crucial step to improving nutrition practices. Athletes should also be aware of the need for long-term dietary planning to ensure lifelong health and wellbeing and should recognise the pleasures of good food choices.

Discipline specific recommendations

Swimming

Pool swimmers should follow a well-planned training diet with a focus on periodising energy and nutrient intakes to optimise training and competition. Intakes should match requirements for energy and nutrients and be timed to maximise the adaption to each training session. Swimmers should recognise the individual nutrition needs of taper, complex competition schedules and the off-season break.

Open water swimming

Open water swimmers are exposed to variable competition and training environments that present unique nutrition challenges. Swimmers should begin races with optimised glycogen stores and in a well-hydrated state. Events may last many hours, so swimmers are encouraged to begin feeding early and to consume carbohydrate (up to 90g per hour according to the duration of the race from a range of carbohydrate sources) and fluid to maintain high swimming speeds.

Water Polo

Water polo requires a combination of endurance, strength, power, swimming speed, agility, tactical awareness, and specific technical skills. A planned nutrition approach incorporating strategies to

facilitate recovery should be implemented following training sessions and matches, particularly when short recovery times are scheduled. Players should commence intensified training sessions and competition well-fuelled and adequately hydrated.

Diving

Divers require a combination of explosive power, flexibility, strength, artistry and courage to achieve success. Divers must ensure adequate energy availability to satisfy the needs of daily training loads by dynamically matching nutrient intakes with the demands of the sport. Nutrition practices should support the achievement of sport-related physique goals, an optimal strength-to-weight ratio, and peak competition performance while assuring good health and well-being. It is important to make suitable foods and fluids available during prolonged practices and competitions to enable appropriate energy and nutrient intakes to be achieved.

Artistic swimming

Artistic swimming is unique amongst the aquatic disciplines as it requires technical precision combined with a high level of fitness involving speed, power, endurance and flexibility. Athletes must achieve artistic mastery while spending a great amount of time breath-holding while upside down underwater. The aesthetic nature of the sport emphasises leanness, so restricted eating behaviour is common. Furthermore, athletes are faced with limited eating opportunities which hinder adequate macronutrient consumption and contribute to micronutrient deficiencies. Therefore, appropriately timed food and fluid intake which provides adequate energy intake and macronutrient consumption should be encouraged.

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