

Module 3. The use of liquids, carbohydrates and electrolytes

Unit 3.1 Sports Drinks

There currently exists a large number of drinks that we can define as “sports drinks”. As the term suggests, it would seem that any type of liquid that can be used in a sports event can be called a sports drink.

In this module, we will explore the advantages and disadvantages of using different drinks in order to classify them according to their adequacy, or lack thereof, for use coupled with physical effort.

Currently, water is presented as a universal liquid and is the most readily available for consumption. Although we have previously seen that it is a useful tool for day-to-day needs, for certain efforts requiring elevated volume and intensity, we must recognize that water does not supply energy and electrolytes “to the cause”. Because of this, it can cause “water intoxication” in an athlete. It is here that certain other drinks come onto the scene, supplying carbohydrates and electrolytes, which are fundamental at particular points during physical effort.

Starting with a brief overview of the history of beverages today known as “sports” drinks, timing and forms of preparation, we will try to understand how and why athletes should use them.

3.1.1 Historical Overview

In the summer of 1965, an assistant trainer at the University of Florida, obsessed with getting maximum performance from his team, the “Florida Gators”, met with a group of scientists to understand why most of his players suffered so much from the heat. Here Doctor Robert Cade and his prestigious group of researchers (Dr. Dana Shires, Dr. H. James Free and Dr. Alejandro De Quesada) come into the story in search of a solution to the problem.

Firstly, they established that, by sweating, the players were affected by the loss of fluids and electrolytes. Concurrently, they lost large amounts of carbohydrates and were unable to restore them.



These discoveries were taken into the laboratory to guide the formulation of a drink that could balance the losses (water, carbohydrates and electrolytes) and help the players to recover after physical exertion.

Thus, other teams began to call this drink "Gator's aid", never knowing that in the future the nickname would become one of the top brands in today's market (Gatorade). The team's results were excellent and their physical performance was vastly improved. They became known as the "second-half team" because that was when they defeated their opponents. The trainer had discovered that his players gained physical advantages from the drink, proving to be less dehydrated and performing better. In 1966, their crowning achievement occurred; for the first time in history, they won the *Orange Bowl* (retrieved from goo.gl/5HHRAS)

In a few years, the product became commercialized and was the first of many glucose-electrolyte solutions (GES). Years later on the market, the improved versions of the product, such as those with glucose polymer solutions (GPS) and varying amounts of electrolytes, declared themselves to be "sports drinks".

The glucose-electrolyte solutions were originally designed to replace lost liquids and carbohydrates. In addition to water, the main ingredients in these solutions are carbohydrates, usually with different combinations of glucose, glucose polymers, sucrose or fructose and some of the main electrolytes lost via perspiration (sodium, chloride, potassium and phosphorous). Levels of sugar vary from 5 to 8% depending on the brand, as do the calories, which fluctuate between 80 and 350 kcal/L (varying in relation to the amount of carbohydrates).

Some brands also include a variety of other substances, such as vitamins (usually B and C), minerals (calcium and magnesium), drugs (caffeine) and herbal products (ginseng).

The glucose polymer solutions are designed to deliver carbohydrates, and at the same time diminish the osmotic concentration of the solution. Osmolarity ranges from 200 to 400 mOsm/L, helping to minimize the effect of gastric emptying on the athlete (Coombes & Hamilton, 2000).

3.1.2 The Role of Sports Drinks

In previous modules, we have gone into detail regarding the importance of ingesting carbohydrates (CHO) while exercising as a tool to delay the onset of fatigue in athletes. Let's remember that CHs are the main fuel source during exercise. If we add to this the research – sustaining that high temperatures can accelerate muscle glycogen – we find that the fusion of "hydration and sports drinks" becomes indispensable to improving physical performance.

Just as Jeukendrup (2014) proposes in the following review, numerous studies have indicated that the need for CHO is incremental in relation to the duration of the exercise (see table 1).

Table 1: CHO Intake while Exercising

DURATION OF EXERCISE	CHO NEEDS	PREFERRED CHO TYPES
30 – 75 minutes	Mouthfuls or Small quantities	SINGLE OR MULTIPLE TRANSPORT CHO
1 – 2 hours	30 grams per hour	SINGLE OR MULTIPLE TRANSPORT CHO
2 – 3 hours	60 grams per hour	SINGLE OR MULTIPLE TRANSPORT CHO
> 2,5 hours	90 grams per hour	MULTIPLE TRANSPORT CHO

Source: Adapted from Jeukendrup, 2014.

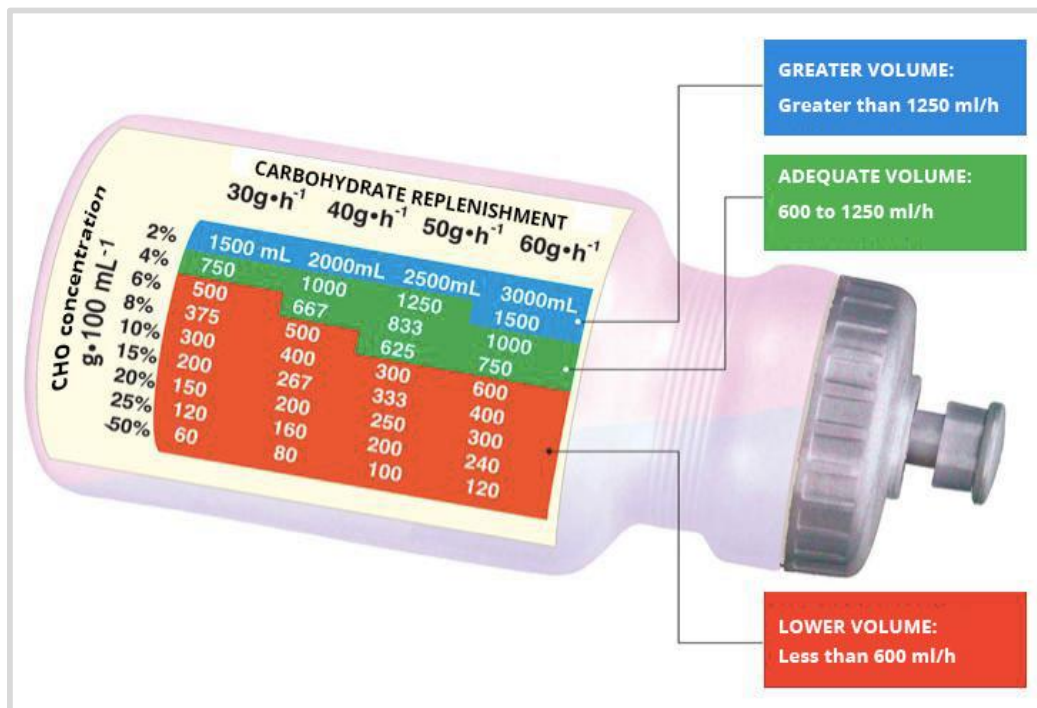
Likewise, research indicates that an adequate quantity of CHO in the solution can help maintain body temperature just as effectively as water, and thanks to the delivery of “sugars”, can improve prolonged performance.

We must pause here because, although CHO delivery in different combinations and concentrations can be beneficial, we must also keep in mind that solutions delivering more than 15-20% of CHO can significantly delay gastric emptying, diminish intestinal absorption and cause gastrointestinal irritation.

In general, CHO solutions that vary from 5 to 8% empty the stomach just as effectively as water during exercise. Compared to water, no significant adverse effects have been observed in these solutions in terms of plasma volume, sweat production, or body temperature regulation. In fact, they can help maintain plasma volume, hepatic glycogen and blood glucose levels during prolonged exercise (Maughan, 2000).

The following figure shows the quantity of liquid we can ingest at a specific concentration, so that the grams of CHO needed for an event can be accessed.

Figure 1: Concentration of CHO According to Liquid Volume



Source: Adapted from McArdle, 2015.

Another role of sports drinks is related to the replenishment of electrolytes in prolonged activities. Here they must mainly compensate for elevated losses of sodium and potassium through sweat.

If electrolytes are not replaced in activities where physical effort lasts over 4 hours (cycling, triathlons, marathons, tennis, etc.), there is a risk of hyponatremia, a condition where blood sodium levels are depleted; a problem we will cover in detail further ahead. During this type of effort, consuming large quantities of water can cause sodium displacement from the extracellular medium to the intestine, generating an accelerated reduction in plasma sodium (Mountain, Chevront & Sawka, 2006).

Sodium is the “electrolyte superstar” that delivers physiological benefits when added to drinks consumed during exercise. Concentrations may vary from 20 to 50 mmol/L (460-1150 mg/L) can stimulate maximum delivery of water and carbohydrates to the small intestine and help maintain the volume of extracellular fluid.

On the other hand, while still important, loss of potassium is lower (4-8 mmol/L) so its replacement is less necessary than that of sodium, at least while exercising. Generally, it is best included in post-exercise drinks which help to replenish losses, as it favors intercellular water retention and helps achieve adequate rehydration.

3.1.3 Designing Homemade Sports Drinks

In their review of the effectiveness of drinks on the market, Coombes and Hamilton (2000) propose a series of guidelines for the optimum sports drink formula, details of which include:

An optimum sports drinks must provide:

- 50 to 80 g of CHO/L;
- 80 to 350 kcal/L;
- more than one type of carbohydrate in the composition (not just glucose);
- osmolarity between 200 and 400 mOsm/L;
- between 20 and 60 mmol/L of sodium (460 to 1380 mg/L).

Stemming from this original proposal and reviewing the nutrients on offer in the current market (see table 2), we can emulate industrial preparation with a homemade version, which is a cost-effective alternative; especially when the implementation costs of an industrial sports drinks are not viable.

Table 2: Composition of Different Types of Sports Drinks on the Market (each 1000 cm³)

Drink	Kcal	CHO (%)	CHO (Gr/l)	Sodium (mg/l)	Potassium (mg/l)
Gatorade	222	5,83%	58,3	444,4	125
Powerade	222	5,83%	58,3	416	97,2
SIS Go	292	7,2%	72	1000	120
GU Drink Mix	195	5,0%	50	694	83,3
Isostar Fast Hydration	288	6,7%	67	700	190

Source: Prepared by the author.

Traditional preparation of homemade sports drinks requires water (bottled or drinkable tap water), orange/grapefruit juice, sugar and table salt. The ingredients that create variability in the composition are the use of tap water, because its sodium content is not always the same. Similarly, not using a precision balance for table salt can create issues with the total quantity that can be added with a teaspoon. The same thing happens with the chemical composition of the citrus fruit CHO, but keep in mind that, as a "homemade concoction", perfectly standardizing this drink is very complex.

Another variable to consider when preparing a homemade sports drink is the quantity of sodium contained in bottled water, if used instead of tap water (approximately 50 mg

Na/L). According to industry standards, these are classified as low sodium content (up to 20 mg Na/L), moderate sodium content (up to 100 mg Na/L) and high sodium content (over 100 mg Na/L).

Although preparation can have variations that modify the chemical composition of the final product (with the addition of maltodextrin, glucose, or even commercial juices in powdered form), the basic ingredients and quantities for the homemade format are shown in the following table.

Table 3: Conventional Preparation of Homemade Sports Drinks

Ingredients	Quantity	CHO (gr/L)	Sodium (mg/L)
Tap water	1000 ml	--	50 mg (*)
And (*) a coffee spoon of table salt (*)	1 gr Salt	--	400 mg
3 tablespoons of sugar	60 gr	60 gr	--
2 Lemons (juiced)	150 gr	8 cc	--
Total	288	68 gr	150 mg
(*) Can be replaced by 1 tablet of 1 gr of salt. Which provides the same.			
(*) May vary close to the area in question or if it is replaced by bottled water.			

Source: Prepared by the author.

We can see that if we respect the suggested quantities, the critical elements of a sports drink – like sodium and CHO – generally contain the same values as those proposed for an ideal sports drink by Coombes & Hamilton (2000).

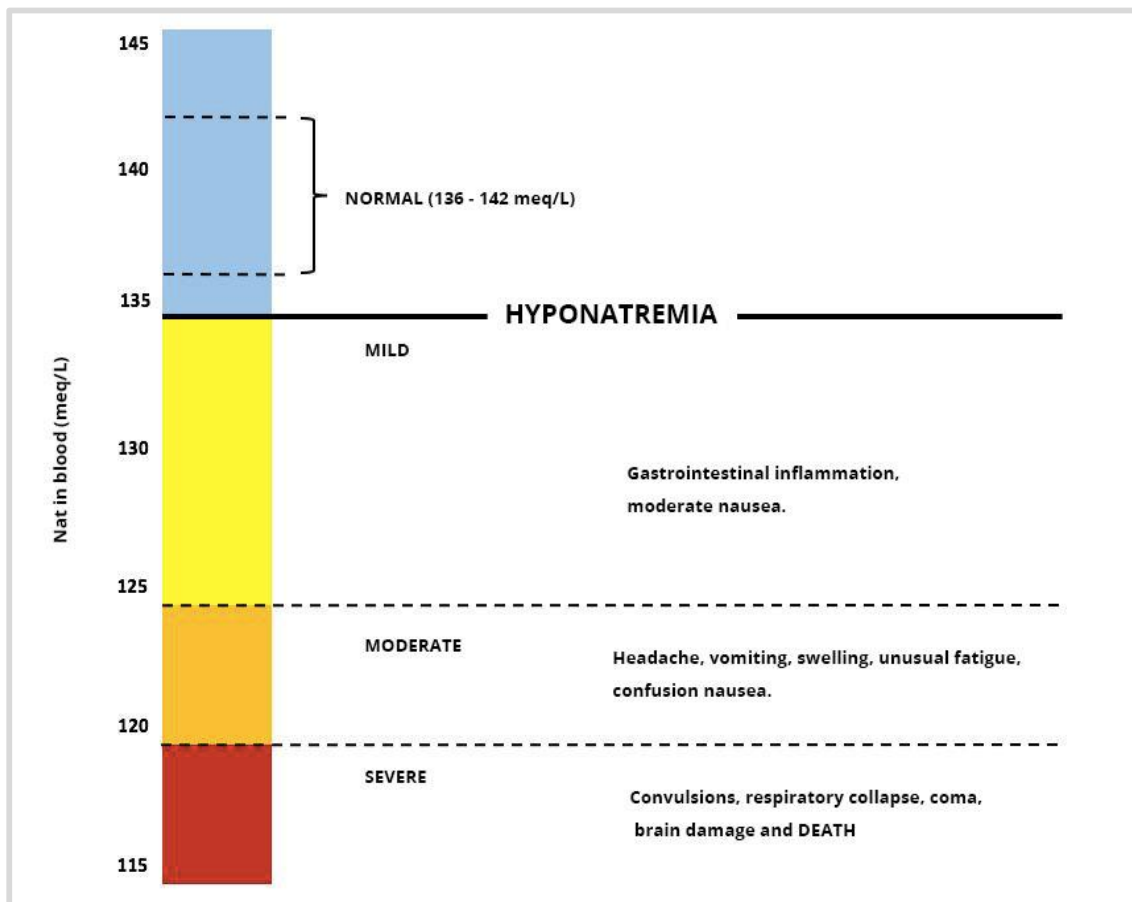
3.1.4 Exercise-Associated Hyponatremia

We have covered the entire module and we have seen the importance of ingesting liquids before, during and after exercise. We have seen the importance of adequate hypotonic water consumption in some cases, but we have realized that in other cases, said consumption can be counterproductive and could cause a complication known as hyponatremia or “water intoxication”.

A decrease in the concentration of plasma sodium causes an osmotic imbalance in the blood-brain barrier, which enables quick entry of water into the brain. This inflammation of cerebral tissue produces a cascade of light to severe symptoms in relation to the amounts of sodium concentration in the blood, and can be seen in figure 2 (Rosner & Kinver, 2007).



Figure 2: Symptoms of Exercise-Associated Hyponatremia (EAH)



Source: Adapted from McGraw Hill, 2011.

Hyponatremia during exercise often appears together with two enabling factors:

- 1) Activity lasting more than 4 or 5 hours.
- 2) Excessive intake of large quantities of plain water during that time.

This is a rather common complication in triathletes, marathon runners and ultra-endurance athletes. It is less common in tennis, for example, where exposure to heat, game duration and excessive simple water hydration combine in a different way.

As well as sodium serum concentration, which we have recently seen, sustained physical activity also magnifies the problem. Urine production diminishes due to the limited blood flow capacity in the kidneys, which diminishes the ability to excrete excess water.

Recommendations for Preventing Hyponatremia

Here is a list of some recommendations to prevent hyponatremia:

- 1) You can prepare a hydration plan to replace liquids in accordance with foreseeable loss and avoid over-hydration.

- 2) You can use sports drinks in those sports where physical exertion lasts more than 3 hours, especially for athletes who “sweat profusely”. In addition to electrolytes, glucose facilitates intestinal water absorption via the glucose-sodium transport mechanism.
- 3) Prior to activities that last a long time and to exposure to high temperatures, it is best to salt food “a bit more”.
- 4) Athletes should be educated so that they can identify “warning signs”, and then suspend their efforts, stop drinking and seek medical attention when appropriate.

Unit 3.2 Other Issues to Consider

Recently, themes regarding sports hydration have received considerable attention. Among them are a range of different studies on the types of drinks that can be used, how to improve the adaptability of liquids to exercise, and supplements that can be used to hydrate athletes.

These points are just some of what we'll be covering throughout this module.

3.2.1 Using Other Drinks in Exercise

With the advancement of the industry and the appearance of different drinks on the market, making the choice has become more complex for athletes. We previously mentioned some points to consider regarding the virtues of sports drinks for athletes, but we didn't address the advantages and disadvantages of other liquids that can be drunk during physical exercise.

Water

Water is a universal liquid and the most available drink in nature. It holds a crucial role in a large number of physiological functions:

- It acts as a medium to allow multiple metabolic reactions.
- As the principle component of blood, it helps transport nutrients, hormones, waste products, and more.
- It is the solvent that helps eliminate soluble metabolic waste by means of the kidneys via the production of urine.
- It is responsible for body temperature regulation and is the principle component in sweat. Its evaporation on the surface of the skin helps dissipate excess body heat.

Nevertheless, as we have seen, in the context of sustained physical activity, it can cause dilution of sodium levels in the blood, thereby causing hyponatremia. Although it is vital for many bodily functions, we must always remember that it neither provides the electrolytes nor the calories at times required by physical effort.

Sugar-Free Sports Drinks

This group of drinks has appeared recently thanks to producers who have decided to expand the market with a "reduced" sugar option. These drinks are based on the fact that they deliver the most important electrolytes during physical effort (sodium and potassium)

without adding calories. Herein lies one of the main problems, as they cannot consistently provide the carbohydrates needed to compensate for the fall in glycogen during activity. Nevertheless, they can be a valid option for individuals who do not “tolerate” sweetened sports drinks, as they imply less effort for adaptation and tolerance in the gastrointestinal tract.

At some points during physical exertion, the redistribution of blood flow is not the same in the stomach as at the beginning of the activity. Here is when athletes often report an intolerance to certain foods, and the same thing happens with sweetened sports drinks. Although, as we will see later, it is a “trainable” process, it is here where the reduced sugar content in these drinks can make tolerance more efficient for athletes.

Perhaps understanding that an athlete’s choice of drink is the sports drink (as it replaces CHO and electrolytes), this group of sugar-free drinks has appeared as an alternative to consider when its consumption is interspersed with that of regular sports drinks, as its greater adaptability in the gastrointestinal tract improves the subject's tolerance.

Energy Drinks

Energy drinks are non-alcoholic, generally carbonated, and basically made with caffeine and CHO with different rates of absorption, as well as other ingredients (amino acids, vitamins, minerals, vegetable extracts, etc.).

The industry markets them as a functional food, as they were designed to deliver a beneficial effect related to a quick sensation of well-being and greater physical or mental strength in the consumer when faced with exerting extra effort.

The concept of an energy drink comes from the calories as well as the vitality delivered to the body by the guarana and the caffeine, which accelerate mental activity and create an energetic sensation.

Generally, carbonation, high CHO content and caffeine are factors that inhibit hydration. Such a composition usually slows stomach emptying and interferes with the absorption of other nutrients in the intestine (Bonci, 2002).

In turn, its consumption tends to generate a higher number of post-effort side effects, such as insomnia, nervousness and irritability, which often interfere with sleep patterns, considered to be a fundamental pillar of athletes’ performance (Salinero, Lara, Abian-Vicente, González-Millán, Areces, Gallo-Salazar, Ruiz-Vicente & Del Coso, 2014).

Oral Serums

The use of oral serums is promoted in many different sports activities, due to their main ingredients: water, electrolytes, carbohydrates. The World Health Organization (WHO) suggests their use for replacing losses due to diarrhea, which is why their concentrations are completely different than those of a sports drink, as the quantity of liquids and electrolytes lost in that way is much higher than those lost through sweat. A serum containing oral rehydration salt ingredients (ORS) from the WHO is shown in the following table:

Table 4: Composition of Standard and Reduced-Osmolarity ORS per the WHO

Composition	Standard ORS via WHO (1975)	ORS reduced osmolarity via WHO (2002)
Glucose (mmol/L)	111	75
Sodium (mEq/L)	90	75
Potassium (mEq/L)	20	20
Chloride (mEq/L)	80	65
Citrate (mmol/L)	10	10
Osmolarity (mOsm/L)	311	245

Source: JAMA, 2004(291):2632-5

In addition to the differences in the concentration of electrolytes, another big problem with their use by athletes stems from their low CHO content (60 g/L vs. 13 g/L) and their rather disagreeable flavor, which can become a significant factor when drinking large quantities is necessary.

3.2.2 Supplements and their Impact on Hydration

The most studied supplements linked to hydration patterns are glycerol, creatine and caffeine. In a brief review, we'll study the supposed advantages and disadvantages of using said supplements during physical exercise.

Caffeine

Caffeine has historically been recognized as a potential diuretic, which is why it is best to avoid it before and during exercise. However, the latest research posits that the problem only occurs when more than 300 mg are consumed before the exertion. Other studies suggest that consumption of around 250 mg does not cause dehydration during rest or while exercising (EFSA, 2015).

Stemming from the latest recommendations and in virtue of the ergogenic effect of caffeine



in athletes (especially on endurance), there is no reason to avoid its consumption if keeping to under 300 mg before activity.

Creatine

In various studies, results indicate that supplements with creatine elevate total body mass. Early changes observed in body weight after ingesting creatine can probably be explained by the increase in body water, especially in intracellular muscular compartments. It is speculated that the reason for increased body fluid is the greater osmotic load associated with the increased concentration of creatine in the cell.

Another study reported on the possible dehydration that it could cause; a factor which promotes muscle cramps.

Some past information suggested that creatine extracted water from vascular spaces (to store itself in intracellular spaces), which could be the cause of heat stress.

In fact, studies that apply more serious research methods report no consistent risk whatsoever of adverse side effects influencing hydration patterns in subjects, other than increased weight due to the increase of intracellular compartments within muscles (Buford, Kreider, Stout, Greenwood, Campbell, Spano, Ziegenfuss, López & Landis, 2009).

Glycerol

Glycerol is a hyper-hydrating agent that is usually used before competition. Its main function is to increase organic water storage, and under certain conditions, it can protect from heat stress. In any case, not all of the research demonstrates that glycerol generates significant effects in thermoregulation, compared to an adequate hydration pattern with plain water before exercising.

The dose generally used is 1 g of glycerol per kg of body mass, added to 1 or 2 liters of water before exercise (its hyperhydration effect lasts up to 6 hours). One of the problems is that its use is quite impractical, and in turn, often causes a series of collateral effects, such as headaches, nausea, dizziness and instability (Goulet, Aubertin-Leheudre, Plante & Dionne, 2007).

Though a relevant topic for the scientific community, the benefits of exogenous glycerol still need further research in order to reinforce these concepts.

3.2.3 Adaptability to Sports Drink Consumption

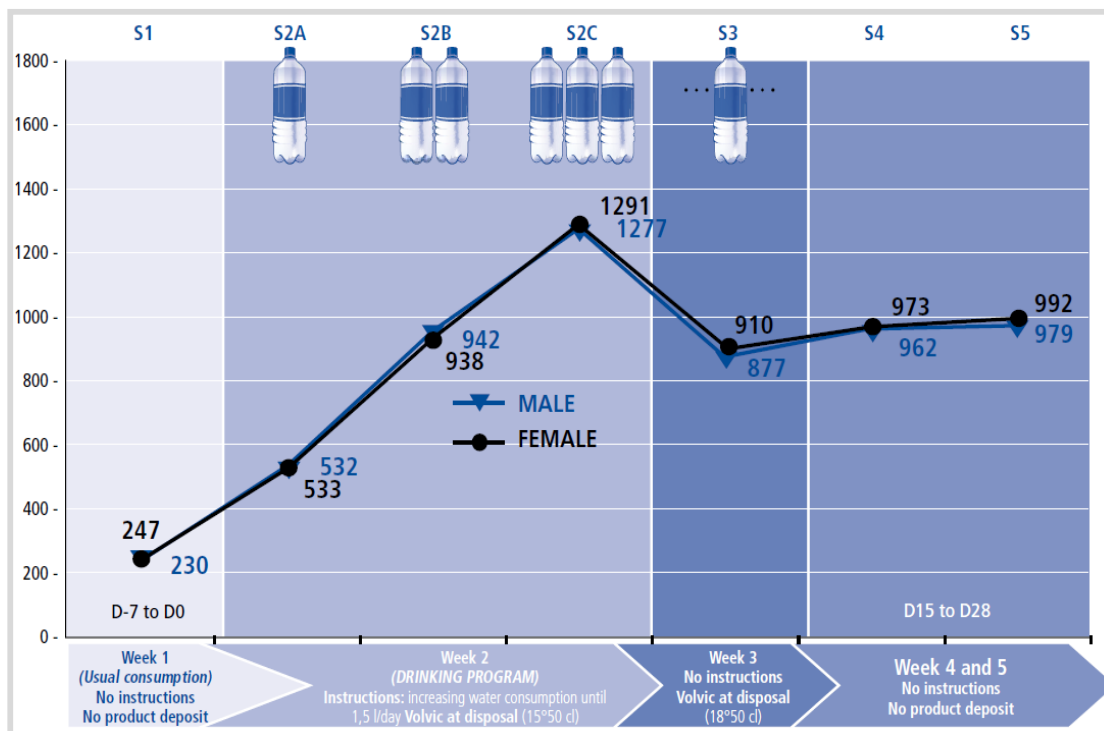
As clearly explained before, it is best to begin a physical task in a state of proper hydration.

The same activity can cause post-effort dehydration if liquids are not ingested. In turn, another concept that we must understand is that if we begin our physical activity in a state of dehydration, it would be very difficult to pass to a state of euhydration or over-hydration during the activity.

That is why the adaptability to liquid consumption before and during exertion is fundamental to avoiding situations that trigger dehydration in athletes. Here we must review the concept of adaptability to liquid consumption in individuals.

It's known that training and adaptability to liquid consumption can be improved in 3 to 4 weeks with an adequate nutritional strategy. In 2010, though a study conducted in 4 French cities, Laurent Le Bellego et al. (2010) demonstrated that test subjects moved from an approximate consumption of 240 ml/day of water to almost 1000 ml/day, using differences strategies (recording liquid intake, increasing the availability of liquids, having pertinent instructions for consumption, etc.).

Figure 3: Adaptability to Liquid Consumption in the Context of a Nutritional Strategy



Source: Laurent Le Bellego et al.

The nutritional choices made by the subjects (whether athletes or not) are influenced by multiple factors, including biological, social and cultural factors. Likewise, they are influenced by information delivered via mass media, advertising, interaction with peers, and obviously, product availability and their access to those products. Here is a key point; as a member of a healthcare team, improvement happens when we communicate with the athlete.

One of the tools that is not usually made available to athletes is nutritional education for improving their performance. Convincing athletes of how important hydration is to performance is the job of their collaborators. There are ample situations where athletes do not hydrate as required during a sports event because this point was not emphasized in the preceding weeks of preparation. Communicating the importance of systematic hydration is complicated (so that it comes naturally later) when the coach or the work group do not allow it to happen during preparation for an event. Only addressing the subject's physical or technical-tactical preparation and ignoring dehydration – and the lack of motor coordination it can cause – is a damaging factor; it is like not knowing all the “rules of the game”. As part of a multidisciplinary team, we must address these points.

Institutions and regulations play their part, in that they do not contemplate hydration as a process vital to athletic performance. Sports with mid-game breaks allow for a better hydration model than those without them. For example, it's much easier to hydrate in sports like basketball or volleyball, the dynamics of which facilitate mid-game pauses, as compared to soccer, where those moments don't exist and hydration is at the discretion of the referee.

Creating modifications in order to better structure these issues would be of vital importance as a strategy to promote changes in habit so that greater consumption of liquids could be allowed during sports events.

3.2.4 Designing Hydration Plans

To create an athlete's hydration plan we must consider two central points:

- 1) The maximum level of dehydration proposed by ACSM, as previously seen, must not exceed 2% of the body weight lost from the beginning to the end of the session;
- 2) We must stipulate, as we have previously seen, the subject's sweat rate in a climate similar to that for which the plan will be designed (i.e., ascertain the sweat rate in temperatures and at humidity levels similar to those for the plan).

With these issues in mind, the design of the diet plan is nothing more than a rule of three, which allows us to reach the total volume of consumption for the event. Next we'll look at an example of how to determine this.

Data:

- Sweat rate (SR): 2.3 L/hour (in conditions similar to the event).
- Athlete's weight: 80 kg.
- Duration of future event: 120 minutes (2 hours).

- Tolerable weight loss according to ACSM: $80 \text{ kg} \times 2\% = 1.6 \text{ kg} = 1.6 \text{ L}$.

Let's review:

- 1) The athlete's maximum loss threshold must not exceed 1.6 liters.
- 2) Supposing that the event lasts 2 hours with a SR of 2.3 L/hour (in a similar climate), around 4.6 liters total will be lost during exercise.
- 3) The maximum acceptable loss (2%) is 1.6 liters, which is why 3 liters of total liquid must be covered in that time ($4.6 - 1.6 = 3 \text{ L}$).
- 4) The ideal plan is established based on SR, so a minimum of 3 liters must be prescribed, at 1.5 liters of liquid/hour if possible, because it is not always feasible for the athlete to drink the ideal amount of liquids.

Once the total amount of liquid to prescribe has been determined, the different types of liquids to use can be listed, following Jeukendrup's (2014) proposal, which we have seen recently.

- *Up to 60 minutes: no CHO delivery.*
- *Between 60 to 120 minutes: 30 g CHO/hr.*
- *Between 120 to 180 minutes: 60 g CHO/hr.*
- *Over 180 minutes: 90 g CHO/hr.*

To conclude our example, we can recommend the following consumption:

- Drink 1.5 liters of water in the first 60 minutes of exercise.
- Drink 1 liter of water + 500 cm³ of a sports drink (delivering 30 g of CHs) in the following hour. As a preventative measure, if the athlete is used to drinking sports drinks, he or she should also drink more of the sports drink (in this case the remaining 1.5 liters) after the second hour.

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