Consensus on drinks for the sportsman. Composition and guidelines of replacement of liquids. Consensus document of the Spanish Federation of Sports Medicine

Nieves Palacios Gil-Antuñano *(Coordinator)*
Luis Franco Bonafonte, Pedro Manonelles Marqueta,
Begoña Manuz González, José A. Villegas García
Working group on nutrition in sport of the
Spanish Federation of Sports Medicine

Separata de Archivos de Medicina del Deporte 2008;XXV(4):245-258

DOCUMENT OF CONSENSUS
ARCHIVOS DE MEDICINA DEL DEPORTE

Volumen XXV
Número 126
2008
Págs. 245-258

CONSENSUS ON DRINKS FOR THE SPORTSMAN. COMPOSITION AND GUIDELINES OF REPLACEMENT OF LIQUIDS

DOCUMENT OF CONSENSUS OF THE SPANISH FEDERATION OF SPORTS MEDICINE

CONSENSO SOBRE BEBIDAS PARA EL DEPORTISTA. COMPOSICIÓN Y PAUTAS DE REPOSICIÓN DE LÍQUIDOS

DOCUMENTO DE CONSENSO DE LA FEDERACIÓN ESPAÑOLA DE MEDICINA DEL DEPORTE

Nieves Palacios Gil-Antuñano
(Coordinator)

Luis Franco Bonafonte

Pedro Manonelles Marqueta

Begoña Manuz González

José A. Villegas García

Working group on nutrition in sport of the Spanish Federation of Sports Medicine

INTRODUCTION

Although a balanced diet and proper hydration are, on the whole, the basis for meeting the nutritional requirements of most people who do sport, there are known to be specific needs that will depend on different factors, such as individual physiological conditions, the type of sport, the moment in the season, training and the competition period[1].

The two demonstrated facts that contribute most to fatigue development during physical exercise are the decrease in carbohydrates stored in the organism in the form of glycogen and the onset of dehydration from loss of water and electrolytes through sweating. Anyone who wants to optimise their sports performance needs to be well nourished and hydrated.

ASSESSMENT OF THE NEED FOR LIQUIDS

The most important replacement as regards physical exertion is the re-establishment of homeostatis, altered by the loss of water and ions. In fact, rises in environmental temperature and humidity increase the quantity of sweat by approximately 1 litre/hour. Sweat evaporation is the most efficient mechanism for avoiding inner core heating, with the serious risk of a heat-related condition posed by temperatures of over 30ºC. Depending on individual variation, the type of exercise and, basically, its intensity, the quantity of sweat can even reach values equivalent to or of over 3 litres/hour[2]. These losses of internal liquid, needed to produce skin cooling through sweat evaporation, lead the sportsman to hyperosmotic hypovolemia-induced dehydration (due to the fact that sweat is hypotonic with respect to plasma). Finally, when the capacity to produce sweat begins to be limited, the inner core goes up in temperature and increases the risk of a serious heat-related condition.

Although among men and women who do not take physical exercise there is a difference in thermoregulation capacity favourable to men (among other reasons because of their greater body surface and lower subcutaneous fat content), when sportspersons of both sexes are compared, the difference is minimised, as the degree of training, acclimatisation, fat content, etc. is similar and, if it were slightly favourable to the man, the women compensate it thanks to their greater efficacy in sweat evaporation[3,4].

Approximately 80% of the energy produced for muscular contraction is released in the form of heat in the organism, which has to be eliminated rapidly to avoid provoking an increase in body temperature above a critical level that would have very negative health consequences. At the same time as the sweat mechanism "cools down" the body, it provokes a major loss of liquids.

Progressive dehydration during exercise is frequent as many sportsmen and women do not ingest enough fluids to replace the losses that

Translated from *Archivos de Medicina del Deporte* 2008;XXV(4):245-258

have taken place. This not only diminishes physical performance but also increases the risk of injuries and can put the health and even the life of the sportsman at risk. That is why it is very important to put together a strategy capable of maintaining an optimum level of body liquid while exercising (both in training sessions and in competitions).

Dehydration affects sports performance because:

- It decreases the obtainment of aerobic energy by the muscle.
- Lactic acid cannot be transported far from the muscle.
- It reduces strength.

According to the proportion of liquids lost, the follow alterations can occur[5-7]:

- Loss of 2%: decrease in thermoregulatory capacity.
- Loss of 3%: decrease in resistance to exercise, cramp, dizziness, greater risk of suffering lypothimia and rise in body temperature to 38 degrees.
- Loss of 4-6%: decrease in muscular strength, contractures, headaches and rise in body temperature to 39 degrees.
- Loss of 7-8%: serious contractures, exhaustion, pins and needles, possible organic failure, heatstroke.
- Loss of over 10%: entails serious risk to life.

That is why, although there are individual characteristics that establish very marked differences between sportspersons (environmental factors, prior acclimatisation, training state, body weight, ingestion of drugs, etc.), it can be said that the first advice that ought to be established as regards fairly intensive physical exercise is the need to replace the liquids lost.

The drop in weight produced by sweat evaporation is highly variable. One simple way of finding out how much water is lost in a physical activity is to weigh oneself before and after the exercise, as in exertions of under 3 hours, water loss from breathing is relatively insignificant, compared to that produced by sweating. If the sportsman weighs himself under the same conditions for several days (when he gets up, for example), the variations may reflect his state of hydration prior to the exertion and, when comparing the weight before and after the physical activity, the degree of dehydration provoked by the exercise can be established[8,9]. Urine density (examined by changes in colour) can also be a supplement for the above observation[10].

ELECTROLYTE NEEDS

Before the liquid lost in the internal medium is eliminated in the form of sweat, its composition is key to determining the quantities of solutes that have to be replaced. However, it has to be remembered that the range of electrolytes in sweat is very wide and varies according to the degree of acclimatisation. The concentration of the sodium ion in sweat ranges from 10 to 70 mEq/L, that of the potassium ion from 3 to 15 mEq/L, that of the calcium ion from 0.3 to 2 mEq/L and that cloride ion from 5 to 60 mEq/L[11]. Owing to the fact that acclimatisation improves the capacity to reabsorb Na^+, people adapted to the environmental conditions of the area have lower Na^+ concentrations in their sweat (a reduction of over 50%).

Electrolytes during exercise

Replacement of ions has a hierarchy based on the clinical situation that can cause each one to alter: the drop in blood sodium levels during physical exertion has led to highly serious situations and even the death of the sportsman[12-15]. Hyponatremia associated with drinking water only in long-lasting exercises has been the cause of serious conditions (disorientation, confusion and even epileptic fits)[16]. During exertions of this kind, the consumption of large quantities of pure water may lead to displacement of Na^+ from the extracellular medium to the intestine, causing an acceleration in the reduction of the plasmatic Na^+. In fact, deaths from hyponatremic encephalopathy have occurred linked with high water consumption (as happened in the 2002 Boston marathon).

The sodium ion is, therefore, the only electrolyte which, if added to the beverages consumed during exercise, provides physiological benefits. An Na^+ concentration of 20 to 50 mmol/L (460-1150 mg/L) stimulates the maximum arrival of water and carbohydrates in the thin intestine and helps maintain the volume of extracellular liquid[1].

Potassium ion losses are much lower (4-8 mmol/L) which, associated with the hyperpotasemia observed in intense physical exertion, makes their replacement less necessary than that of the sodium ion, at least during the time the execution of the exertion lasts, although it is advisable to include it in beverages used to replace the losses once the physical activity has ended, as potassium favours water retention in the intracellular space, thereby helping to achieve adequate rehydration[17,18].

Electrolytes after exercise

Although electrolytic replacement, after the exertion has ended, depends on a large number of circumstances (duration, temperature and humidity of the area, acclimatisation, etc.), some fundamental facts can mark the guidelines:

- The outcome of ingesting water only in an organism dehydrated by sweat losses (as happens after intense exercise and/or during the course of it) is a rapid drip in plasmatic osmolality and sodium concentration which, in turn, reduces the impulse to drink that stimulates diuresis, with potentially serious consequences such as hyponatremia. Hence, rehydration after physical effort is not achieved adequately with water alone[19]. The quantity of urine eliminated after physical effort is inversely proportional to the sodium ingested. This is the only ion to have proved its efficacy in liquid replacement studies.
- In exercise, during muscular contraction, there is a loss of intracellular K^+, due to muscular activity and, as a result, an increase in the plasmatic concentration of this cation; after exercise, the intracellular K^+ concentration in the muscles is recovered and the plasmatic levels of this ion rapidly return to their basal values. There is no evidence that the losses of this ion, as a result of exercise, are important enough to affect the sportsman's health or performance[20]. In any case, it has to be remembered that potassium helps achieve adequate rehydration (it optimises water retention), so its inclusion in beverages used after the exercise is positive.

CARBOHYDRATES

Although hydration is the first step to take with respect to the performance of physical exercise, other factors linked with the exertion itself must be considered. In this respect, it is known that the concentration of glycogen in the liver and muscles used during the activity marks the capacity to maintain a prolonged effort in aerobic sports[21]. In fact, training in sports of this kind consists, mainly, of getting the organism accustomed to using fats to the maximum as a source of energy (through their oxidation) and of increasing glycogen reserves in the liver and muscles[22]. Glycogen storage is limited (10-12% of the weight in the liver and 1-1.5% of the weight in the muscles). Glycogen savings can be achieved maintaining glycemia through the exogenous supply of glucose. If compared with the intake of water only, by adding carbohydrates to a solution, consuming it at a rate of 1 g/min, glucose oxidation in the liver is reduced by as much as 30%[23]. In this respect, it is demonstrated that the supply of carbohydrates in rehydration beverages during exertion improves the sportsman's performance[24].

The quantity of carbohydrates to supply in the beverage is marked by the following conditioning factors:

– The limit of use of glucose by the sportsman, which stands at 60 g/h[25].

– The limit of gastric emptying and of intestinal absorption of the solution, which determine the assimilation of the liquid drunk[26].

As regards the limit of use of glucose, the maximum amount of it that should be supplied when doing sport can be achieved by drinking 1200 ml in an hour of a solution containing 8% of carbohydrates in the form of glucose, sucrose and/or maltodextrins. Glucose absorption is subject (to begin with) to an active transport mechanism mainly dependent on the sodium ion, and on the paracellular route when high luminal concentrations are present. Fructose is absorbed by facilitated diffusion (in a transport system linked with disaccharidases) and by glucose facilitated transport. These different and complementary absorption routes make the mix of carbohydrates recommendable. There are actually no conclusive data on the type of carbohydrate that gives the best result in beverages. Some authors argue slightly in favour of using polysaccharides (maltodextrin) due to the lower rise in osmolality that they produce, together with glucose and fructose[27]. Glucose increases the activity of the Na^+-K^+-ATPasa, at least *in vitro*, which is a good reason for including it in these formulations[28]. For other authors, sucrose, because it tastes better, is the most suitable carbohydrate.

The American College of Sports Medicine (ACSM)[29] recommends that the beverage should have a high glycemic index (better still, a high glycemic load) and maintains that greater use of carbohydrates is achieved by a mixture of them (i.e. glucose, sucrose, fructose, maltodextrin). Of the carbohydrates used, glucose, with 97, is the one with the highest glycemic index, followed by sucrose (glucose plus fructose), with an index of 65[30].

As regards gastric emptying, the following factors have to be taken into account:

– Circumstances that stimulate emptying:

  - The increase in gastric volume: it produces distension of the wall of this organ, provoking myenteric reflexes which increase the activity of the pyloric pump, speeding up gastric emptying.
  - The presence of gastrin, which stimulates the pyloric pump slightly.

– Factors that inhibit emptying:

  - The degree of distension of the duodenum.
  - Irritation of the duodenal mucose.
  - The degree of acidity of the duodenal chyme.
  - The degree of osmality of the chyme.
  - Excessive amount of proteins or fats in the stomach.
  - The presence of hypotonic or hypertonic liquids (particularly the latter), as they trigger enterogastric reflexes which slow down or inhibit gastric emptying.
  - Prior dehydration.
  - Exercise intensity of over 80% of the V02max.

The time it usually takes the stomach to empty 1 litre of liquid varies from 1-1.5 h. but this gastric emptying rate depends on a broad set of factors, among which the determining factors are the nature of the solutes and the energy value of the beverage[31]. As of the approximate quantity of 600 ml, the greater the gastric content volume, the faster the emptying. As the volume decreases, evacuation slows down. For that reason, to keep it at an adequate rate is it advisable to replace the amounts eliminated by the repeated ingestion of liquids.

The absorption of carbohydrates, water and electrolytes takes place in the first portions of the thin intestine (duodenum and yeyunum). It is calculated that optimum quantities of intestinal absorption are between 600-800 ml for water, and some 60 grams for glucose. When more than a litre of liquids per hour are drunk, the surpluses can accumulate and produce intestinal discomfort.

THE BEVERAGE FOR THE SPORTSMAN

According to Spanish law, Royal Decree 1444/2000 of 31 July[32], beverages for sportsmen are considered among food preparations for dietary and/or special regimes, under the heading on foods adapted to intense muscular wear, above all for sportsmen and women. These beverages have a specific composition for achieving rapid absorption of water and electrolytes and preventing fatigue, and have three main objectives[33]:

- To provide carbohydrates that maintain an appropriate concentration of glucose in the blood and delay the exhaustion of glycogen deposits.
- The replacement of electrolytes, particularly of sodium.
- Hydric replacement to avoid dehydration.

These beverages should have good palatability, so it is reasonable to think that they will be consumed more easily than water on its own.

In February, 2001, the European Commission's Health and Consumer Protection Directorate General, through the Scientific Committee on Food, drew up a report on the composition of food and beverages intended to meet the expenditure of great muscular effort, especially among sportsmen and women[1].

The document indicates that specially adapted foods and liquids help solve specific problems in order to achieve an optimum nutritional balance. These beneficial effects are not confined only to sportsmen and women who take regular and intensive muscular exercise, but also people who, in their jobs, make major exertions in adverse conditions, and people who during their leisure time do physical exercise and train.

It indicates that the sports beverage should supply carbohydrates as a fundamental source of energy and should be efficient in maintaining optimum hydration or in rehydrating, recommending the following margins in the composition of the beverages to take while doing sport[1]:

- Not less than 80 kcal per litre.
- Not less than 350 kcal per litre.
- At least 75% of the calories will come from carbohydrates with a high glycemic index (glucose, sucrose, maltrodextrins).
- Not more than 9% of carbohydrates: 90 grams per litre.
- Not less than 460 mg of sodium per litre (46 mg per 100 ml / 20 mmol/l).
- Not more than 1150 mg of sodium per litre (115 mg per 100 ml / 50 mmol/l).
- Osmolality between 200-330 mOsm/kg of water.

OTHER COMPONENTS OF REPLACEMENT BEVERAGES

Anti-oxidants

During physical exercise, oxygen consumption by the muscle can increase more than 100 times[34,35] and oxygen consumption by the whole organism can increase up to 20 times. It is therefore reasonable to suppose that the mitocondrial production of oxygen is equally increased. Reactions among superoxides trigger other reactive oxygen species, hydrogen peroxide and, in the last instance, the hydroxile radical[36,37]. It can be considered, therefore, that during intense physical effort oxidative stress takes place.

The ingestion of antioxidants to minimise the damage caused by reactive species generated in the electron transport chain has produced different results when assessing an increase in performance, so their presence in beverages for sportsmen and women is not essential[38-44].

Ramified amino acids

Very long-lasting aerobic sports are not as dependent on metabolic factors as those that last for under three hours. There are sound arguments for considering that there are hormonal and neurotransmission-related factors involved in fatigue, in fact this kind of fatigue is called “central”[45] and basically involves serotonin (5-HT). In this respect, it has been proved that serotonin increase is directly linked with fatigue in rats[46] and presumed to be linked in humans, too. Owing to the fact that 5-HT cannot cross the hematoencephalic barrier (HEB) and its precursor, tryptophan (TRP), can, the concentration of this neurotransmitter in the brain will be highly dependent on the concentration of free TRP in the blood[47]. It is logical to suppose, on this point, that on finding out the very direct relationship that exists between the metabolism of an amino acid (tryptophan) and the brain 5-HT concentration, an effort was made to manipulate the ingestion of amino acids during sport, basically to provide competitors with the absorption and transport of an amino acid precursor of a neurotransmitter related with the onset of fatigue[48], particularly bearing in mind that it has been fully demonstrated in rats that the intake of ramified amino acids such as valin, prevent the increase in 5-HT concentration in the hypofield during intensive effort and considering that the direct relationship between the increase of 5-HT and fatigue during strenuous exercise has been demonstrated, too, in rats[49]. The first factor that was tried to be manipulated was the competition with TRP in transport through the HEB. In this sense, numerous studies were performed in which ramified amino acids were supplied to the sportsman during the exertion. The result was an overall consensus that, while the ingestion of drugs that increase 5-HT recapture accelerates fatigue[50,51], ramified amino acids (RAA) do not cause changes in the sportsman’s perception of fatigue or performance[52-56]. At the same time, clinical trials looking for the relationship between the ingestion of different diets before exertion and the TRP/RAA relationship before, during and after the exertion, have shown that changes in the TRP/RAA relationship during exertion do not affect the sportsman’s performance[57]. As a result, while the use of carbohydrates in beverages for sportsmen and women is fully accepted, not only for its ergogenic effects, but because they improve cognition and humour[58], the intake of RAA is not consensuated.

Proteins

The benefit of adding intact proteins to the sportsman’s beverage is currently under debate. Some studies demonstrate the anabolic effort of lactic serum after prolonged effort[59]. Another very important effect of the proteins of milk serum is the increase in the glycogen deposit[60], essential for accelerating recovery after long-lasting exercise[61]. Research studies have also been undertaken that have confirmed less muscular damage when taking beverages with protein during effort[62].

The ideal proteinic concentrate for adding to a beverage for sportspersons would be milk serum (the liquid left on removing casein and fat from milk after adding whey). It is composed of beta-lactoglobulin, alpha-lactoalbumin, albumin (from bovine serum), lactoferrin, immunoglobulins, lactoperoxidases, glycomacropeptides, lactose and minerals. Another alternative is just to provide the serum lactoproteins, i.e. milk serum deprived of lactose, which can be useful in people with lactase deficit.

Fats

In principle, it is not advisable to include fats in replacement beverages, on the basis of the caloric increase that they represent and on the decrease in gastric emptying that they entail. However there are two arguments that have justified different studies on including fatty acids in replacement beverages.

On the one hand, it is known that free fatty acids –which increase in plasma with the lypolisis induced by long-lasting physical exercise- increase the fraction of plasma free tryptophan (TRP) when competing with its transport mediated by albumin. The free TRP increases when the concentration of fatty acids in plasma rises above 1 mmol/L and this concentration occurs when muscular glycogen runs out, resulting in the increase of fatty acids in plasma.

The research then focused on the fatigue of the sportsman, as there is known to be an close relationship between the presence of free tryptophan, ramified amino acids (RAA) competing for the transport of the tryptophan through the hematoencephalic barrier (HEB) and free fatty acids competing for the transport of tryptophan in plasma by means of albumin. In this respect, clinical trials have been conducted already, seeking the possible decrease in the sensation of fatigue using n-3 fatty acids. However, these trials have not proved satisfactory yet, thus Huffman, *et al.*[63], in 2004 using dosages of 4 g of n-3 (500 mg capsules containing 300 mg of EPA and 200 mg of docosahexaenoic acid) performed a study on popular runners of both sexes, without finding statistically significant decreases in free TRP or less perception of effort, or an increase in performance, although there was a tendency to improve performance among individuals who consumed n-3, leaving the authors with the possibility that it was the low number of individuals studied (5 men and 5 women) that had detracted statistical power from the study. These researchers, in their conclusions, left the door open to future trials conducted with more people and a matter of great interest was left pending solution: what was the gender difference in the results, which, without being statistically significant, showed a very marked tendency towards the women, who would be more sensitive to improvement in performance on taking n-3 fatty acids.

These last studies, conducted by Spanish researches, demonstrate that DHA (docosahexaenoic acid) taken chronically in low dosages (0.5 g) and in the form of a structured lipid can be an important complement in replacing homeostatis during moderate and even intensive physical effort[64].

HYDRATION GUIDELINES: MANAGING THE BEVERAGE FOR THE SPORTSMAN

Hydration before exercise

Sportsmen should be well hydrated before starting training sessions or competitions. Body weight variation can be used as an indicator for adequate hydration. An individual can be considered to be properly hydrated if his weight in the morning before eating or drinking anything is stable: it varies less than 1% day to day[65]. In women, the menstrual cycle phase has to be taken into account, as weight may be gained during the luteal phase because there is more water retention. Dehydration will be minimum with a loss of 1 to 3% of body weight, moderate between 3 to 5% and severe if it is over 5%[66].

If sufficient beverages are ingested with meals and there is a proper rest period (8-12 hours) since the last training session, it is highly likely that the sportsman is euhydrated[67]. If that is not possible, the American College of Sports Medicine recommends the following prehydration programme[68]:

- To drink 5 to 7 ml/kg slowly in the 4 hours before starting the exercise. If the individual cannot urinate or if the urine is dark or highly concentrated, intake should be increased, adding 3 to 5 ml/kg more in the last 2 hours before exercise.

- Beverages with 20-50 mEq/L of sodium and meals with sufficient salt can help stimulate thirst and retain the fluids consumed.

- In hot, humid atmospheres, is it advisable to take about half a litre of liquid with mineral salts during the hour prior to starting the competition, divided into four intakes every 15 minutes (200 ml every quarter of an hour). If the exercise to be performed is going to last longer than an hour, it is also recommendable to add carbohydrates to the beverage, especially in the last two intakes[69,70].

The ingestion of water together with glycerol is not recommendable before exercise, as it does not improve sports performance and can cause side-effects such as: nauseas, gastrointestinal discomfort, headaches and an increase in body weight. Moreover the hyperhydration that it produces increases the risk of developing hyponatremia[71,72].

Enhancing the flavour of fluids is one way of promoting their consumption. The flavour will depend to a large degree on the temperature (15-21ºC), on the quantity of sodium it contains and on the type of carbohydrate used[73-75].

REHYDRATION DURING EXERCISE

The aim is to get the sportsmen to ingest enough liquid to maintain the right hydro-electrolytic balance and plasma volume during exercise.

Thirty minutes after starting effort, it starts to be necessary to compensate for liquid loss, and after an hour it is essential.

It is recommended to drink between 6 and 8 millilitres of liquid per kilogram of weight and hour of exercise (approximately 400 to 500 ml/h or 150-200 ml every 20 minutes). It is not advisable to take more fluid than necessary to compensate for hydric deficit[76]. These current recommendations contrast with the ones that were made until recently: 10 to 12 ml/kg/h and to drink as much as possible to avoid a drop in body weight during exercise[77].

The ideal temperature of the liquids should be between 15-21 degrees. Colder beverages slow down absorption and occasionally provoke lypothymia and fainting fits, while hotter beverages are not appealing and as a result, less quantity will be drunk[73].

POST-EFFORT REHYDRATION

Rehydration should start as soon as exercise ends. The main aim is the immediate re-establishment of the cardiovascular, muscular and metabolic physiological function, by remedying liquid loss and solute build-up during the course of exercise.

If the drop in weight during training or the competition were over 2% of body weight, it is advisable to drink even if not thirsty and to salt foods more[78,79]. Ingestion of at least 150% of weight loss is recommended in the first 6 hours after exercise, to cover the liquid eliminated both by sweat and by urine and thus recover the hydric balance. The best prepared individuals develop more efficient cooling systems (sweating), so they should consume more liquid.

Plasma volume increase is directly linked with the volume of liquid ingested and sodium concentration. Resynthesis of hepatic and muscular glycogen (used up during exercise) is greater in the first two hours after exertion. As a result, post-exercise rehydration beverages should contain both sodium and carbohydrates, and should be taken as soon as possible.

Recent studies show that exercise induces, in the active muscles, the release of interleukin 6, which in turn stimulates cortisol release, favouring both immunosuppressor processes. Supplementation with carbohydrates decreases the concentration of interluekin 6, reduces the drop in number and activity of the lymphocytes, minimising the immunosuppressive effects of exercise[80].

EVIDENCE-BASED CONSENSUS

Physical activity increases sweat production, which produces loss of water and electrolytes, particularly under adverse thermoregulation conditions.	Level Ia evidence
Losses of water and electrolytes in different sports display great individual variability.	Level Ia evidence
If homeostatis is not restored before exertion, the sportsman becomes dehydrated.	Level Ia evidence
Dehydration affects performance in sports.	Level Ia evidence
Rehydration with water alone does not solve the problem and can even aggravate it with a hyponatremia.	Level Ia evidence
Sodium is the only ion that has proved its efficacy in liquid replacement studies.	Level Ia evidence

Carbohydrate supply in rehydration beverages improves the sportsman's performance.	Level Ia evidence
It is important to take carbohydrates during physical exercise, particularly in exertion lasting over 1 hour, and immediately after it.	Level Ia evidence
The energy load of the beverage and its osmolality determine the speed of gastric emptying.	Level Ia evidence
There is no gender difference in thermoregulation between sportsmen and women.	Level IIa evidence
Sportsmen can have a fairly approximate idea of their degree of dehydration by observing urine colour and the weight difference before and after exertion.	Level IIa evidence
It is advisable to add the potassium ion in replacement beverages after physical exertion as it helps retain water in the intracellular space, although its concentration should not be over 10 mmol/L.	Level IIb evidence
The other ions are irrelevant in liquid replacement after exertions lasting under 4 hours.	Level IV evidence
The presence of proteins in post-competitive beverages favours muscular anabolism.	Level Ib evidence
The presence of structured lipids derived from DHA diminish the use of carbohydrates during exertion.	Level Ib evidence
The presence of antioxidants in replacement beverages may be advisable.	Level Ib evidence
The ingestion of different beverages helps improve rehydration by increasing hydric ingestion (more tempting).	Level Ib evidence
The presence of ramified amino acids in pre-competition beverages diminishes so-called "central fatigue".	Level IIb evidence

Evidence level

- Ia: The evidence comes from meta-analysis of well-designed random controlled trials.
- Ib: The evidence comes from at least one random controlled trial.
- IIa: The evidence comes from at least one well-designed non-random controlled study.
- IIb. The evidence comes from at least one well-designed, not completely experimental study, such as cohort studies. It refers to the situation in which the application of an intervention is beyond the researchers' control, but its effect can be evaluated.
- III: The evidence comes from well-designed non-experimental descriptive studies, such as comparative studies, correlation studies or case studies and controls.
- IV: The evidence comes from documents or opinions of committees of experts or clinical experiences of authorities of prestige or case series studies.

GENERAL RECOMMENDATIONS

Recommendation 1

It is very important for someone who performs a sporting activity to be properly hydrated all day long, i.e. before, during and after the physical exertion. Hydration during physical activity is incomplete in many sports because of the characteristics of the exertion and sweat losses. In these cases, hydration should be optimised as much as possible.

Recommendation 2

Beverages for sportsmen used during training sessions or in competitions themselves should have a calorie level of between 80 kcal/1000 ml and 350 kcal/1000 ml, of which at least 75%

should come from a mix of high glycemic load carbohydrates such as glucose, sucrose, maltodextrins and fructose. The range differences are established according to the characteristics of the sport, environmental conditions and the specific individuality of the sportsman (tolerance, etc.).

Recommendation 3

Beverages for sportsmen used during training sessions and in competitions themselves should have a sodium ion content in the range of 20 mmol/l (460 mg/l) and 50 mmol/l (1,150 mg/l) according to the heat, intensity and duration of the exertion. The osmolality of such beverages should be comprised of between 200-330 mOsm/ kg of water, and should not under any circumstances exceed 400 mOsm/ kg of water.

Recommendation 4

Replacement beverages used after training or competitions should have a calorie content of between 300 kcal/1,000 ml and 350 kcal/1,000 ml, of which at least 75% should come from a mix of high glycemic load carbohydrates such as glucose, sucrose, maltodextrins and fructose.

Recommendation 5

Beverages for sportsmen used for immediate post-exertion should have a sodium ion content in the range of 40 mmol/l (920 mg/l) and 50 mmol/l (1,150 mg/l). Likewise, they should provide potassium ion in the range of 2-6 mmol/l. The osmolality of those beverages should be comprised of between 200-330 mOsm/ kg of water, without exceeding 400 mOsm/ kg of water.

BIBLIOGRAPHY

1. **Report of the Scientific Committee on Food on composition and specification of food intended to meet the expenditure of intense muscular effort, especially for sportsmen.** Access 20/03/2006. URL. http://europa.eu.int/comm/food/fs/sc/scf/out64_en.pdf

2. **Rehrer NJ.** Fluid and electrolyte balance in ultra-endurance sport. *Sports Med* 2001;31:701-15.

3. **Kaciuba-Uscilko H, Grucza R.** Gender differences in thermoregulation. *Curr Opin Clin Nutr Metab Care* 2001;4:533-6.

4. **Kenny GP, Jay O.** Evidence of a greater onset threshold for sweating in females following intense exercise. *Eur J Appl Physiol* 2007;101:487-93.

5. **Barbany JR.** *Alimentación para el deporte y la salud*. Barcelona: Martínez Roca 2002.

6. **González Alonso J, Mora Rodríguez R, Bedow PR, Coyle EF.** Dehydratation reduces cardiac output and increase system and cutaneous vascular resistance during exercise. *J Appl Physiol* 1995;79:1487-96.

7. **Maughan RJ, Gleeson M.** *The Biochemical Bases of Sports Performance.* Oxford: Oxford University Press 2004.

8. **Maughan RJ, Watson P, Evans GH, Broad N, Shirreffs SM.** Water balance and salt losses in competitive football. *Int J Sport Nutr Exerc Metab* 2007;17:583-94.

9. **Murray B.** Hydration and physical performance. *J Am Coll Nutr* 2007;26(5Suppl):542S-548S.

10. **Harvey G, Meir R, Brooks L, Holloway K.** The use of body mass changes as a practical measure of dehydration in team sports. *J Sci Med Sport* 2007 Sep 19.

11. **Cheuvront SN, Carter R 3rd, Sawka MN.** Fluid balance and endurance exercise performance. *Curr Sports Med Rep* 2003;2:202-8.

12. **Ayus JC, Arieff A, Moritz ML.** Hyponatremia in marathon runners. *N Engl J Med* 2005;353:427-8.

13. **Noakes TD, Sharwood K, Collins M, Perkins DR.** The dipsomania of great distance: Water intoxication in an Ironman triathlete. *Br J Sports Med* 2004;38:E16.

14. **Hsieh M, Roth R, Davis DL, Larrabee H, Callaway CW.** Hyponatremia in runners requiring on-site medical treatment at a single marathon. *Med Sci Sports Exerc* 2002;34:185-9.

15. **Rosner MH, Kirven J.** Exercise-associated hyponatremia. *Clin J Am Soc Nephrol* 2007;2:151-61.

16. **Baylis P.** Hyponatremia and hypernatremia. *Clin Endocrinol Metab* 1980;9:625-37.

17. **Nadel ER, Mack GW, Nose H.** Influence of fluid replacement beverages on body fluid homeostasis during exercise and recovery. En: Gisolfi CV, Lamb DR (eds). *Perspectives in exercise science and sports medicine*. Volume 3. Fluid homeostasis during exercise. Carmel: Benchmark Press 1990:181-205.

18. **Maughan RJ, Leiper JB, Shirreffs SM.** Factors influencing the restoration of fluid and electrolyte balance after exercise in the heat. *Br J Sports Med* 1997;31:175-82.

19. **Shirreffs SM, Taylor AJ, Leiper JB, Maugham RJ.** Post-exercise rehydration in man: effects of volume consumed and drink sodium content. *Med Sci Sports Exerc* 1996;28:1260-71.

20. **Reher N, Bechers E, Brouns F, Hoor F, Saros W.** Effects of dehydration on gastric emptying and gastrointestinal distress while running. *Med Sci Sports Exerc* 1990;22:790-5.

21. **Brooks GA, Mercier M.** The balance of carbohydrate and lipid utilization during exercise: the "cross-over" concept. *J Appl Physiol* 1994;76:2253-61.

22. **Hawley JA, Hopkins WG.** Aerobic glycolytic and aerobic lipolytic power system. *Sports Med* 1995;19:240-50.

23. **Burke LM, Claassen A, Hawley JA, Noakes TD.** Carbohidrate intake during prolonged cycling minimizes effect of glycemic index of preexercise meal. *J Appl Physiol* 1998;85:2220-6.

24. **Wagenmakers AJM, Brouns F, Saris WHM, Halliday D.** Oxidation rates of orally ingested carbohydrates during prolonged exercise in men. *J Appl Physiol* 1993;75:2774-80.

25. **Wallis GA, Yeo SE, Blannin AK, Jeukendrup AE.** Dose-response effects of ingested carbohydrate on exercise metabolism in women. *Med Sci Sports Exerc* 2007;39:131-8.

26. **Costill DL, Saltin B.** Factors limiting gastric emptying during rest and exercise. *J Appl Physiol* 1974;37:679-83.

27. **Currell K, Jeukendrup AE.** Superior endurance performance with ingestion of multiple transportable carbohydrates. *Med Sci Sports Exerc* 2008;40:275-81.

28. **Green HJ, Duhamel TA, Foley KP, Ouyang J, Smith IC, Stewart RD.** Glucose supplements increase human muscle in vitro Na^{+}-K^{+}-ATPase activity during prolonged exercise. *Am J Physiol Regul Integr Comp Physiol* 2007;293:R354-362.

29. **American College of Sports Medicine (1997) Position Stands.** Exercise and fluid replacement: Author. Retrieved 31/05/08 from the World Wide Web: http://www.acsm-msse.org/pt/pt-core/template-journal/msse/media/0207.pdf.

30. **Wolever TMS, Jenkins DJA, Jenkins AL, Josse RG.** The glycemic index: methodology and clinical implications. *Am J Clin Nutr* 1991;54:846-54.

31. **Maughan RJ.** Fluid and electrolyte loss and replacement in exercise. *En:* Harries M, Williams C, Stanish WD, Micheli LL (eds). *Oxford Textbook of Sports Medicine.* Oxford: Oxford University Press. 1994;82-93.

32. **Real Decreto 1444/2000, de 31 de julio, por el que se modifica la Reglamentación Técnico-Sanitaria para la elaboración, circulación y comercio de preparados alimenticios para regímenes dietéticos y/o especiales, aprobada por el Real Decreto 2685/1976, de 16 de octubre.** *BOE,* 183:27561-2 (1 de agosto de 2000).

33. **Palacios N.** Nutrición y ejercicio físico. *Nutr Hosp* 2000;XV(Sup):31-40.

34. **Tsai K, Hsu TG, Hsu KM, Cheng H, Liu TY, Hsu CF, Kong CW.** Oxidative DNA damage in human peripheral leukocytes induced by massive aerobic exercise. *Free Radic Biol Med* 2001;31:1465-72.

35. **Inoue T, Zhouseng M, Sumikawa K, Adachi K, Okochi T.** Effect of physical exercise on the content of 8-hydroxy¬deoxyguanosine in nuclear DNA prepared from human lymphocytes. *Japan J Cancer Res* 1998;84:725-50.

36. **Nielsen HB, Hanel B, Loft S, Poulsen HE, Pedersen BK, Diamant M, Vistisen K, Secher NH.** Restricted pulmonary diffusion capacity after exercise is not an ARDS-like injury. *J Sports Sci* 1995;13:109-13.

37. **Pilger A, Germadnik D, Formanek D, Zwick H, Winkler N, Rudiger HW.** Habitual long-distance running does not enhance urinary excretion of 8-hydroxydeoxyguanosine. *Eur J Appl Physiol and Occup Physiol* 1997;75:467–9.

38. **Morillas-Ruiz JM, Villegas García JA, López FJ, Vidal-Guevara ML, Zafrilla P.** Effects of polyphenolic antioxidants on exercise-induced oxidative stress. *Clin Nutr* 2006;25:444-53.

39. **Davison G, Gleeson M.** Influence of acute vitamin C and/or carbohydrate ingestion on hormonal, cytokine, and immune responses to prolonged exercise. *Int J Sport Nutr Exerc Metab* 2005;15:465-79.

40. **McAnulty SR, McAnulty LS, Nieman DC, Morrow JD, Utter AC, Henson DA, Dumke CL, Vinci DM.** Influence of carbohydrate ingestion on oxidative stress and plasma antioxidant potential following a 3 h run. *Free Radic Res* 2003;37:835-40.

41. **Palmer FM, Nieman DC, Henson DA, McAnulty SR, McAnulty L, Swick NS, Utter AC, Vinci DM, Morrow JD.** Influence of vitamin C supplementation on oxidative and salivary IgA changes following an ultramarathon. *Eur J Appl Physiol* 2003;89:100-7.

42. **Ciocoiu M, Badescu M, Paduraru I.** Protecting antioxidative effects of vitamins E and C in experimental physical stress. *J Physiol Biochem* 2007;63:187-94.

43. **Gomez-Cabrera MC, Domenech E, Romagnoli M, Arduini A, Borras C, Pallardo FV, Sastre J, Viña J.** Oral administration of vitamin C decreases muscle mitochondrial biogenesis and hampers training-induced adaptations in endurance performance. *Am J Clin Nutr* 2008;b87:142-9.

44. **Morillas-Ruiz J, Zafrilla P, Almar M, Cuevas MJ, Lopez FJ, Abellan P, Villegas JA, Gonzalez-Gallego J.** The effects of an antioxidant-supplemented beverage on exercise-induced oxidative stress: results from a placebo-controlled double-blind study in cyclists. *Eur J Appl Physiol* 2005;95:543-9.

45. **Newsholme EA, Blomstrand E.** The plasma level of some amino acids and physical and mental fatigue. *Experientia* 1996;52:413-5.

46. **Yamamoto T, Newsholme EA.** Diminished central fatigue by inhibition of the L-system transporter for the uptake of tryptophan. *Brain Res Bull* 2000;52:35-8.

47. **Williams W, Shoaf SE, Hommer D, Rawlings R, Linnoila R.** Effects of acute tryptophan depletion

on plasma and cerebrospinal fluid tryptophan and 5-hydroxyindoleacetic acid in normal volunteers. *J Neurochem* 1999;72:193-9.

48. **Gomez-Merino D, Bequet F, Berthelot M, Riverain S, Chennaoui M, Guezennec CY.** Evidence that the branched-chain amino acid L-valine prevents exercise-induced release of 5-HT in rat hippocampus. *Int J Sports Med* 2001;22:317-22.

49. **Soares DD, Lima NR, Coimbra CC, Marubayashi U.** Evidence that tryptophan reduces mechanical efficiency and running performance in rats. *Pharmacol Biochem Behav* 2003;74:357-62.

50. **Wilson WM, Maughan RJ.** Evidence for a possible role of 5-hydroxytryptamine in the genesis of fatigue in man: administration of paroxetine, a 5-HT reuptake inhibitor, reduces the capacity to perform prolonged exercise. *Exp Physiol* 1992;77:921-4.

51. **Struder HK, Hollmann W, Platen P, Donike M, Gotzmann A, Weber K.** Influence of paroxetine, branched-chain amino acids and tyrosine on neuroendocrine system responses and fatigue in humans. *Horm Metab Res* 1998;30:188-94.

52. **Mittleman KD, Ricci MR, Bailey SP.** Branched-chain amino acids prolong exercise during heat stress in men and women. *Med Sci Sports Exerc* 1998;30:83-91.

53. **Davis JM, Alderson NL, Welsh RS.** Serotonin and central nervous system fatigue: nutritional considerations. *Am J Clin Nutr* 2000;72:573-8.

54. **Blomstrand E, Hassmen P, Ek S, Ekblom B, Newsholme EA.** Influence of ingesting a solution of branched-chain amino acids on perceived exertion during exercise. *Acta Physiol Scand* 1997;159:41-9.

55. **Wagenmakers AJ.** Amino acid supplements to improve athletic performance. *Curr Opin Clin Nutr Metab Care* 1999;2:539-44.

56. **Hargreaves MH, Snow R.** Amino acids and endurance exercise. *Int J Sport Nutr Exerc Metab* 2001;11:133-45.

57. **Blomstrand E, Saltin B.** BCAA intake affects protein metabolism in muscle after but not during exercise in humans. *Am J Physiol Endocrinol Metab* 2001;281:365-74.

58. **Lieberman HR, Falco CM, Slade S.** Carbohydrate administration during a day of sustained aerobic activity improves vigilance, as assessed by a novel ambulatory monitoring device, and mood. *Am J Clin Nut* 2002;76:120-7.

59. **Tipton KD, Elliott TA, Cree MG, Wolf SE, Sanford AP, Wolfe RR.** Ingestion of casein and whey proteins result in muscle anabolism after resistance exercise. *Med Sci Sports Exerc* 2004;36:2073-81.

60. **Morifuji M, Sakai K, Sanbongi C, Sugiura K.** Dietary whey protein increases liver and skeletal muscle glycogen levels in exercise-trained rats. *Br J Nutr* 2005;93:439-45.

61. **Borsheim E, Aarsland A, Wolfe RR.** Effect of an amino acid, protein, and carbohydrate mixture on net muscle protein balance after resistance exercise. *Int J Sport Nutr Exerc Metab* 2004;14:255-71.

62. **Baty JJ, Hwang H, Ding Z, Bernard JR, Wang B, Kwon B, Ivy JL.** The effect of a carbohydrate and protein supplement on resistance exercise performance, hormonal response, and muscle damage. *J Strength Cond Res* 2007;21:321-9.

63. **Huffman DM, Altena TS, Mawhinney TP, Thomas TR.** Effect of n-3 fatty acids on free tryptophan and exercise fatigue. *Eur J Appl Physiol* 2004;92:584-91.

64. **López Román J, Luque A, Martínez A, Villegas JA.** Modifications in oxidative damage in sportsmen after docosahexaenoic acid (DHA) ingestion. *J Int Sports Nut.* 2008 Jun 21. [Epub ahead of print].

65. **Opliger RA, Bartok C.** Hydratation testing of athleties. *Sports Med* 2002;32:959.

66. **Casa DJ, Armstrong LE, Hillman SK, Montain SJ, Reiff RU, Rich BSE, Roberts WO, Stone JA.** National Atheltic Trainers' Association Position Statement: Fluid Replacement For Athletes. *J Athletic Training* 2000;35:212-24.

67. **Institute of Medicine, Water.** En: Dietary references intakes for water, sodium, chloride, potassium and sulphate. Washington: National *Academy Press,* 2005:73-185.

68. **American College of Sports Medicine.** Exercise and Fluid Replacement. Special Communications. *Med Sci Sports Exerc* 2007;39:377-90.

69. **Shirreffs SM, Maughan RJ.** Volumen repletion after exercise induced volume depletion in humans: replacement of water and sodium losses. *Am J Physiol* 1998;274:F868-F875.

70. **Gorostiaga E, Olivé R.** Adaptaciones al clima y al horario de Pekín'08. *Comité Olimpico Español.* 2007:15-45.

71. **Gorostiaga E.** *Adaptación al ejercicio en ambiente caluroso*. Madrid: COE. 2004.

72. **Mountain SJ, Cheuvront SN, Sawka MN,** Exercise associated hyponatremia: quantitative analysis for understand the aetiology. *J Sports Med* 2006;40:98-106.

73. **Brouns F.** Aspectos de la deshidratación y la rehidratación en la práctica del deporte. En: *Necesidades nutricionales de los atletas.* 1ª Ed. Barcelona: Paidotribo, 1995:67-86.

74. **Costill DL, Sparks KE.** Rapid Fluid replacement after thermal dehydratation. *J Appl Physiol* 1973;34:299-303.

75. **Maughan RJ, Owen JH, Shirrefs SM, Leiper JB.** Post-exercise rehydratation in man: effects of electrolyte addition to ingested fluids. *Eur J Appl Physiol* 1994;69:209-15.

76. **Hew-Butler T, Verbalis JG, Noakes TD.** Updated fluids recommendation: position statement from the International Marathon Medical Directors Association (IMMDA). *Clin J Sport Med* 2006;16:283-92.

77. **Convertino VA, Amstrong LE, Coyle EF, Mack GW, Sawa MN, Senay LC Jr., Sherman WM.** American Collage of sports Medicine Position stand. Exercise and fluid replacement. *Med Sci Sports Exerc* 1996;28(1):i-vii.

78. **Peronnet F, Thibault G, Ledoux M, Briuson GR.** *Le marathon. Equilibre Energetique, alimentation et entrainement du coureur sur route*. Quebec: Decarige et Vigot, 1991.

79. **Burke LM.** Nutritional needs for exercise in the heat. Biocem. *Physiol. Amol. Integr. Physiol* 2001; 128:735-48.

80. **Gleeson M, Bishop NC.** Special feature for the Olimpics: effects of exercise on the immune system modification of immune responses to exercise by carbohydrate, glutamine an anti-oxidant supplements. *Inmunol Cell Biol* 2000;78:554-61.