Development of individual hydration strategies for athletes

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Abstract

Athletes are encouraged to begin exercise well hydrated and to consume sufficient amounts of appropriate fluids during exercise to limit water and salt deficits. Available evidence suggests that many athletes begin exercise already dehydrated to some degree, and while most fail to drink enough to match sweat losses, some drink too much and a few develop hyponatraemia. Some simple advice can help athletes to assess their hydration status and to develop a personalised hydration strategy that takes account of exercise, environment and individual needs. Pre-exercise hydration status can be assessed from urine frequency and volume, with additional information from urine colour, specific gravity or osmolality. Change in hydration during exercise can be estimated from the change in body mass that occurs during a bout of exercise. Sweat rate can be estimated if fluid intake and urinary losses are also measured. Sweat salt losses can be determined by collection and analysis of sweat samples, but athletes losing large amounts of salt are likely to be aware of the taste of salt in sweat and the development of salt crusts on skin and clothing where sweat has evaporated. An appropriate drinking strategy will take account of pre-exercise hydration status and of fluid, electrolyte and substrate needs before, during and after a period of exercise. Strategies will vary greatly between individuals and will also be influenced by environmental conditions, competition regulations and other factors.

Key words: dehydration, sweat, fluid balance; sodium
Introduction

Exercise is accompanied by an elevation of metabolic rate that will cause body temperature to rise if heat loss mechanisms are not invoked. In most exercise situations, the elevation of body temperature is small, but when hard exercise is combined with high ambient temperatures or restricted heat loss, substantial (2-3°C) rises in core temperature are observed (Nadel, 1988). Exertional heat illness, which can be fatal, is the most serious outcome of a failure to limit the rise in body temperature (Sutton, 1990; Sawka et al, 2007). While this condition is observed most often in hot and humid environments, it can occur even in cool weather. It is most commonly observed in athletes, military personnel and industrial workers, but may affect anyone exposed to prolonged heat stress.

Long before there is a risk to health, exercise performance is reduced in the heat. Even when it is only warm (about 20°C) endurance capacity is less than at 10°C (Galloway & Maughan, 1998). It is also well established that a fluid deficit incurred prior to exercise can increase physiological strain and reduce performance. Prior diuretic-induced loss of about 1.5-2% of body mass was shown to reduce performance in track races at distances of 1500m, 5000m and 10000m (Armstrong et al, 1985). Cheuvront et al (2003) have undertaken an extensive review of published studies examining the effects of a body water deficit on exercise performance. The available evidence led the authors to conclude that in situations of exercise in a warm environment (defined as an ambient temperature greater than 30°C), a loss of 2-7% of body mass consistently decreased endurance exercise performance. However, the extent of the performance decrements was highly variable, ranging from a reduction of only 7% to a 60% decline in performance. A less consistent picture was apparent when the endurance exercise was undertaken in temperate conditions. It was concluded that dehydration by 1% to 2% of body mass had no effect on endurance exercise performance when the exercise duration was less than 90 min, but performance was impaired when the level of dehydration was greater than 2% of body mass and the exercise duration was longer than 90 min. A water loss equivalent to 2% or more of body mass appears to reduce endurance exercise performance in both temperate and hot environments, especially when the duration of exercise is in the order of 90 min or more. Casa et al (2000a) reported that oral replacement of even 50% of a 4% body mass loss during a 20 min break was effective in restoring exercise capacity (mean performance time 35±4 min) compared to a trial where no rehydration was allowed (mean performance time 19±3 min). It must, of course, be recognised that performance effects that are highly meaningful to the athlete may be far below the limits of detection when crude laboratory measures of performance are used (Hopkins, 2001). Even when a positive effect on performance is not seen, taking drinks does not make performance worse unless an excessive amount is consumed or the composition is inappropriate.

The performance of complex tasks, such as those involved in many team sports, is also impaired at relatively low levels of fluid deficit. McGregor et al (1999) showed that performance of a soccer skill test, which involved dribbling
a ball between a line of 7 cones each 3m apart, deteriorated by about 5% when it was undertaken after simulated soccer activity when no drinking was allowed; in contrast, performance was maintained when drinks were given. The mean body mass loss of their subjects was 2.4% when no fluid was given and 1.4% when fluids were given. Similarly, in a study investigating the motor skill performance of cricket bowling (Devlin et al, 2001), subjects were dehydrated by 2.8% of their body mass and their performance was compared to that in a trial they had drunk flavoured water and limited their dehydration to 0.5% of body mass. There was no influence of trial on bowling speed, but bowling accuracy, as determined by line and distance, was significantly worse when undertaken in the dehydrated state. Edwards et al (2007) reported that performance of a soccer-specific fitness test was worse after an exercise period without fluid intake, where body mass loss was 2.4% of initial body mass, than when sufficient fluid was given to limit mass loss to 0.7%.

The effects of dehydration on performance are apparent at rather small levels of water deficit, but, as highlighted above, the relative insensitivity of many of the tests of performance used and the potentially confounding effects of the methods used to induce a fluid deficit, mean that the literature is far from clear. There are undoubtedly also effects of mild dehydration on cognitive function and on mood (Shirreffs et al, 2004, Petri et al, 2006). What is clear is that a loss of body water – if sufficiently severe – will impair both physical and mental performance, but depending on the aspect of performance measured, this may be apparent after a 1%, 5% or 10% loss of body mass.

The general consensus is that it is better to drink water than to drink nothing during prolonged exercise in a warm environment, but drinks with CHO and electrolytes may promote better performance (Sawka et al, 2007). This has been shown using various exercise modes, intensities and durations in differing environmental conditions and with both male and female subjects of varying levels of fitness. Maughan et al (1989) showed that exercise time to fatigue was about 70 min when no drink was given, 76 min when 100 ml of water was given every 10 min during exercise, 79 min when a concentrated carbohydrate drink was given at the same rate and 91 min when a dilute carbohydrate-electrolyte drink was given. Below et al (1995) later showed that the effects of providing fluid and carbohydrate were independent and additive.

It has long been known that very prolonged exposures to hard physical work in hot environments will lead to muscle cramps in susceptible individuals and that ingestion of water and salt (sodium chloride), but not of water alone, can reduce the frequency and intensity of muscle cramps (Moss, 1923; Talbott and Michelsen, 1933). More recent data, mostly from tennis (Bergeron, 2003) and from American football (Stofan et al, 2005; Eichner, 2007), have suggested that similar cramps may occur in athletes and that they are more likely to occur in players who sweat profusely and especially in those with a high sweat sodium concentration.

This means that athletes, soldiers, industrial workers and others exposed to exercise and thermal stress must consider their hydration status before beginning exercise, the need for fluid, electrolyte and substrate replacement
during exercise, and the need for restoration of water and electrolyte balance after exercise. This requires a consideration of what to drink, when to drink, and how much to drink. Noakes (2007) has argued repeatedly that the only advice needed is to drink according to the dictates of thirst, but there is ample evidence of inappropriate drinking behaviours in many sports situations. At its most serious, excessive fluid intakes can lead to hyponatraemia with potentially fatal consequences (Almond et al, 2005). Some of this is perhaps due to inappropriate advice directed at inexperienced athletes, who then ignore the normal physiological signals that provide an impetus to fluid intake. However, it is also important to recognise that practical considerations and competition regulations impose limitations on access to fluids in many situations. While some sports, such as, for example, tennis, allow frequent opportunities for drinking at regular intervals during a game, football (soccer) and most other team sports make no such provision. Players may not be able to drink according to the dictates of thirst, but should take advantage of the available opportunities, especially in hot weather competition. It is not unknown for teams at elite level to ensure that stoppage of play for treatment of an injury occurs at times that are convenient for players to take drinks.

Sweat rates and sweat composition depend on the ambient temperature and humidity and on exercise intensity, but they also vary greatly between individuals (Shirreffs et al, 2006). This calls into question any advice that prescribes a fixed drinking regimen, and the most recent Position Stand from the American College of Sports Medicine (Sawka et al, 2007) has suggested that fluid intake during prolonged exercise should be sufficient to limit any body mass loss to less than 2% of the pre-exercise mass and that athletes should never drink so much that they gain body mass during exercise. This latter caution may, however, not hold true if an athlete begins exercise in a severely dehydrated state. No single recommendation is best for all individuals in every situation, and development of an individualised hydration strategy is essential for the protection of health and preservation of performance. The need for education of athletes and for the individualisation of drinking strategies was emphasised by Casa et al (2000b).

The aim of this brief review is to examine some of the methodologies that can be applied to assessment of athletes for the development of an individualised rehydration strategy.

**Assessment of pre-exercise hydration status**

There is no universal agreement on the definition of the optimum pre-exercise hydration status, nor is there a good index of euhydration that can be applied. Some of the various options that can be used to assess hydration status have been described in detail by many authors over many years including Armstrong et al (1994), Shirreffs (2000), Armstrong (2005), Kavouras (2002) and Cheuvront and Sawka (2005). The primary variables that are homeostatically regulated are blood volume and plasma osmolality, but both are subject to short term variation in response to posture change, exercise, food and fluid intake and a number of other factors, so neither is a good index of hydration status (Armstrong et al, 1994; Popowski et al, 2001). Popowski et
al (2001) showed that changes in plasma osmolality tracked well with progressive changes in body mass during exercise in the heat (to a 5% loss of body mass). Under well-controlled conditions, plasma osmolality increased by ~5 mOsm/kg for every 2% loss of body mass by sweating, and during post-exercise water ingestion, values returned towards baseline. Kovacs et al (1999), however, showed that urinary markers, including osmolality, colour and electrical conductance, did not correlate well with hydration status after exercise. This finding is not surprising during periods of rapidly changing body water content, and it should be recognised that such measurements have no value.

These findings, however, cannot be generalised to other situations, such as thermal sweating without exercise, and it must also be recognised that the distribution of water losses between the vascular space, the extracellular space and the intracellular space will be affected by both the rate of sweating and degree of sweat loss (Costill, 1977). Urine osmolality and specific gravity were less sensitive than plasma osmolality and showed delayed responses. Armstrong et al (1994) showed that urine indices may be more sensitive to small changes in hydration status than are blood-derived indices when measures are made over a period of days rather than minutes or hours, and have suggested the use of urine colour in field settings when urine osmolality or specific gravity measures are not possible. Blood-derived indices may change from minute to minute depending on factors such as posture, acute changes in tissue osmolality (such as those resulting from a short sprint that will elevate osmolality markedly for a few minutes), acute effects of fluid ingestion, etc. The urine values will be relatively insensitive to these transient changes. An alternative measure that is simple and inexpensive is urine conductivity, which is closely related to osmolality (Shirreffs and Maughan, 1998).

Urine colour is determined primarily by the amount of urochrome, a breakdown product of haemoglobin, present in the sample (Diem, 1962). When large volumes of urine are excreted, the urine is dilute and solutes are excreted in a large volume. This generally gives the urine a very pale colour. When small volumes of urine are excreted, the urine is concentrated and the solutes are excreted in a small volume. This generally gives the urine a dark colour. Armstrong et al (1998) have investigated the relationship between urine colour and specific gravity and conductivity. Using a scale of 8 colours (Armstrong, 2000), it was concluded that a linear relationship existed between urine colour and both specific gravity and osmolality of the urine and that urine colour could therefore be used in athletic or industrial settings to estimate hydration status when a high precision may not be needed. Urine colour may be influenced by a number of dietary factors. Dark yellow or orange urine can be caused by recent use of B complex vitamins or carotene. Betacyanins, the red compounds present in beetroot, may cause a reddish colour in the urine if consumed in large amounts and a few other food pigments may have similar effects. A few artificial food colours and medications can cause a green or blue colouring and this can depend on the pH of the sample. Athletes who routinely use these products should be aware of these changes: urine colour will still be darker if dehydrated and the important thing is to look for changes from normal.
It is important to recognise that the acute responses to posture, food intake and changes in body water content mean that none of the proposed markers of hydration status is likely to be reliable at times when stability of these factors is not assured. Because of this, the first sample passed in the morning on rising is frequently selected as the testing time (Cheuvront and Sawka, 2005). Nonetheless, these markers have been used to assess hydration status of football players and other athletes reporting for training, where the sample collected is not the first passed that day (Maughan et al, 2004; 2005). It might be argued, however, that the athlete who ingests a substantial volume of fluid between rising and the beginning of training may be well hydrated at the start of training even though the morning urine sample suggests otherwise. If more than a few hours elapse between rising and the beginning of training, fluid losses that are not replaced during that period may result in a fluid deficit at the start of training. The longer the interval between waking and training, the greater the probability that the waking urine sample will not reflect hydration status at the beginning of training. Ballauff et al (1991) have reported that, at least in children aged 6-11 years, there is no circadian rhythm in the urine osmolality, providing some further support for the suggestion that measurements may be made on samples collected at different times of day, provided that there is some appreciation of the potential confounding factors.

Although single values may be of limited usefulness in this situation, an individual who has a consistently high urine osmolality when about to begin a training session or competition is likely to be in a chronic fluid deficit to some degree. There is some evidence of a positive correlation between pre-training urine osmolality and the volume of fluid ingested during a training session where fluids are freely available (Maughan et al, 2005). While this seems logical – athletes who begin training with a higher urine osmolality may be likely to drink more due to a greater sensation of thirst – this relationship has not been seen in all populations studied. A urine osmolality of more than about 900 mosmol.kg\(^{-1}\) is consistent with a body water deficit of about 2% of body mass (Shirreffs and Maughan, 1998). The American College of Sports Medicine position stand suggests that a urine osmolality equal to or less than 700 mosmol.kg\(^{-1}\) is indicative of euhydration (Sawka et al 2007).

Bioimpedance methods can be used to estimate total body water content, and have attracted much attention, as the equipment required is relatively inexpensive, and the technique is straightforward and minimally invasive. However, acute changes in body water content are not reliably detected by the method, and it is sensitive to posture (Shirreffs and Maughan, 1994), skin temperature (Gudivaka et al, 1996) and other factors unrelated to body water content (O’Brien et al, 2002). The lack the precision and accuracy inherent in the methodology, together with the various confounding factors that influence results, limit its use for hydration monitoring (Institute of Medicine, 2005).

Methodological issues
As mentioned above, samples may be collected on waking, or may be collected immediately prior to training. The choice of collection will be affected by several factors and interpretation of the results must take account of this.
Although there is no published evidence of a significant effect, it seems wise to collect a sample in mid-stream or to collect and mix the whole void before retaining a sample. White polystyrene or polycarbonate drinking cups are commonly available by water fountains in locker rooms and can be conveniently used for sample collection by both male and female athletes. Only a few microlitres are required for measurement of osmolality, but it is probably convenient to collect between 5-30 ml in an appropriate clear specimen tube or white cup as described above. This allows the athlete to relate the colour of the sample to the measurement of specific gravity or osmolality. If a clear tube is used, it should be held against a white background for colour assessment. In view of the sensitivity of athletes about analysis of samples for WADA-prohibited substances, numerical identifiers rather than names should be used on all samples.

Specific gravity measurement by refractometry or reagent impregnated strips for urinalysis (eg Bayer Multistix, Bayer Diagnostics) has the advantage of using apparatus that is inexpensive to purchase and to operate, requires little operator skill, is portable, and can be used in the field without requiring an electricity supply. Measurement of osmolality requires a relatively expensive instrument that is not easily transported and requires an electricity supply. The osmometer requires calibration before each use with known standard solutions, and some technical competence on the part of the operator is essential. Osmolality is now most commonly measured by freezing point depression, but equipment using vapour pressure analysis is also used.

Samples for osmolality analysis are generally stable for some days at room temperature or on refrigeration. Some precipitation of calcium salts is likely after a short period of storage. This will not affect the osmolality or specific gravity to any significant degree, but the turbidity that ensues will preclude a reliable measure of colour. The precision of the method will depend on the equipment used and on the individual operator, but highly reproducible results should be obtainable.

Interpretation of findings
Athletes should be made aware that both health and performance may be at risk if exercise begins in a state of severe dehydration. Personal observations are the preferred option, with the athlete taking responsibility for monitoring of urine frequency, volume and colour. Regular monitoring is much preferred to single spot measures due to the factors that may confound a single measurement. Athletes should be alert to any change from their normal, but athletes who are chronically in fluid deficit may be accustomed to infrequent urination and to a dark urine colour. Laboratory measurement of specific gravity or osmolality may be seen by the athlete and coach as having more credibility and can be used periodically to reinforce other measures. A pre-training or pre-competition urine osmolality in excess of 900 mosmol kg\(^{-1}\) should be taken as a need to increase fluid intake: values in excess of 700 should be conveyed to the athlete as being borderline and perhaps indicating a need for increased fluid. Values of less than 200 mosmol kg\(^{-1}\) likely indicate the recent ingestion of a large amount of fluid. It is not unknown for athletes to manipulate samples: any sample that is cold on delivery for analysis should
be viewed as suspect unless there is a good reason for a time delay between collection and delivery.

**Change in hydration status and sweat loss during exercise**

The amount of sweat lost during training or competition can be estimated from changes in body mass, with corrections applied for any fluid intake and any urine passed. Fluid intake can be assessed easily by change in mass of drinks bottles, provided that the athletes does not spit out fluid or use it to pour over their skin. Some of the body water loss is not in the form of sweat, but rather as respiratory water loss, and this route of water loss can be substantial during hard work in dry environments.

Sweat loss will be influenced by a number of factors, including especially the exercise intensity and duration, the environmental conditions, the amount of clothing worn, and the aerobic fitness and acclimation status of the individual. There is also a large individual variability that appears not to be explained by these factors. Single measurements are therefore of limited value: they provide comparative data on athletes within a group, but may not help the individual to develop a strategy that will meet the needs in different environments. Drinking behaviours will also change in different environments and will be influenced by the ease of access to fluids and the choice of drinks on offer.

The effects of potential confounding factors on the interpretation of body mass changes has been discussed in detail by Maughan et al (2007): for practical purposes, they can generally be ignored. A loss of body mass of more than 2-3% usually results in some loss of performance and a gain of body mass is to be discouraged.

**Methodological issues**

Accurate measurement of body mass change requires a balance readable to 10 or 20 g. Small errors, however, are generally unimportant and a precision of 0.1 kg may be adequate. The measurement period should be long enough to ensure that sweat loss is sufficient for the mass change to be recorded with a reasonable degree of precision – probably at least 10 times the readability of the balance. Measurements should ideally be made with subjects nude, as clothing will absorb an unknown and variable amount of sweat and will thus weigh more after sweat loss than before. Where an accurate result is required, subjects should shower and towel dry before the first measurement of mass and repeat this process before the post-exercise measurement to ensure the same degree of wettedness of skin and hair. Where nude measurements are not possible, subjects should wear minimal clothing and should change into identical dry clothing for the post-exercise measurement. It may be convenient to ask subjects to urinate and defecate if necessary prior to the first measurement as any urine or feces passed during the measurement period should be collected and weighed. This is conveniently done using a dietetic measuring scale, which is typically readable to 1-2 g. The weight of any food or fluid consumed during the measurement period should also be measured.
Athletes should be cautious about measurements made on different scales, and measures made on different scales should not be compared. Domestic bathroom scales may not give an absolute value that is correct, but can usually give a reliable measure of a change in weight, provided that simple precautions are followed. This means ensuring a stable, level and hard base on which to place the scale and placing a marker on the scale to ensure consistent positioning of the feet.

Interpretation of findings
A loss of body mass in excess of 1-2% of the starting mass may be a reason for concern, and is at least something that should be discussed with the athlete (Table 1). For some individuals, this may not be detrimental to performance, but for most athletes, increasing fluid intake might be advisable. It is important to recognise that single measurements may not be applicable to other exercise situations or other environmental conditions. Sports scientists working with athletes should try to ensure that monitoring occurs in a variety of exercise situations: single measurements may be difficult to interpret.

The athlete’s hydration strategy should take account not only of the amount of fluid that is required, but also of other nutrient needs such as carbohydrate and energy. One liter of a typical sports drink contains about 60 g of carbohydrate, providing 240 kcal. Where very high fluid losses are encountered, the energy intake that accompanies use of these drinks may exceed the athlete’s energy budget. Diluting sports drinks with water will also dilute the electrolyte content, so the potential for conflict in meeting the needs for water, electrolytes and carbohydrate must be considered. Individual taste preferences will also vary between athletes and also over time in any individual: taste fatigue is likely when large volumes are consumed, so a variety of beverages should be available.

Salt loss
Along with water, large sweat losses will lead to a loss of electrolytes, especially sodium and chloride, with smaller amounts of potassium, and smaller still amounts of calcium, magnesium, iron and other minerals. Sweat is invariably hypotonic relative to body fluids, but the composition is influenced by many different factors, including sweating rate, diet, and acclimation status, but there remains a large inter-individual variability even when these factors are constant (Robinson and Robinson, 1954). Given the potential link between salt loss and muscle cramps, it seems important to identify those athletes with large salt losses which may predispose to exercise-related cramp (Stofan et al, 2005). There are also concerns that high dietary salt intake may adversely affect blood pressure and cardiovascular risk, so it would be unwise to recommend that all athletes consume a high salt diet or consume drinks with a high sodium content during exercise.

Methodological issues
The composition of sweat can be assessed in several different ways, and the method of choice will depend on several factors. While some variant of the
whole body washdown technique will give the most precise result (Shirreffs and Maughan, 1997), for most practical purposes the regional absorbent patch method is preferred. In essence, this consists of the application of an absorbent swab to an area of skin that has been cleaned and dried. The swab is covered with an adhesive non-porous film to prevent evaporation of sweat. After a suitable time interval, the patch is removed and the sweat extracted for analysis. The method of extraction will depend on the size of the swab used and the amount of sweat present: if there is a substantial volume of sweat, the most convenient method may be to put the sweat into the barrel of a small (eg 5 or 10 ml) syringe and express the sweat by depressing the plunger. If the sweat volume is too small for this to be effective, the patch can be placed into a suitable container (eg 30 ml) which is then sealed. The weight of sweat in the patch is determined gravimetrically, and a known volume (about 1-2 ml) of deionised water added: after thorough mixing, a sample is removed for analysis. Alternatively, the patch can be added to a centrifuge tube with a filter and the sweat removed after centrifugation. Regardless of the method used, care must be taken to ensure no evaporation of sweat can take place from the patch after removal from the skin.

Measurements of sweat composition may be made at different body sites, and it has long been known that there are regional differences in the sweat electrolyte content: Johnson et al (1944) ascribed the first report of this to Kittsteiner in 1911. The normal practice, therefore, is to make measurements at several sites and to combine the results as an arithmetic mean or to use a weighting factor to account for regional differences in composition. Sites that are commonly used include the forehead, forearm, chest, back, thigh and calf. Lemon et al (1986) derived several equations for estimation of whole body urea loss in sweat based on regional sampling at the upper back, lower back, chest, stomach and thigh. Patterson et al (2000) compared sweat samples obtained from eleven regional collection sites with the whole body washdown method, and found that the sodium concentration at the calf and thigh was more highly correlated with the washdown values than was the case for composite data from 4 or 8 regional sites. The use of a single sampling site, however, will tend to increase the potential for error.

The ionic composition of sweat can be measured using a variety of different methods. For nutritional recommendations, sodium is the major ion of interest, and is normally measured by flame photometry, ion chromatography or ion selective electrode. The precision of the analytical method is good (coefficient of variation of about 1%) relative to the variation in sodium content with sweating rate, at different body sites and between individuals. However, the information necessary to systematically investigate the test – retest repeatability of measurements of sweat composition is not in the published literature at present.

The normal range for sodium concentration of human sweat is about 10-80 mmol l\(^{-1}\). Values outwith this range are not impossible, but should be treated with caution. High values are encountered in individuals with cystic fibrosis (mean values are in excess of 100 mmol l\(^{-1}\); Wallis, 1997) and in a few rare genetic conditions. Values in excess of 80 mmol l\(^{-1}\) are most likely to be the
result of contamination of the sample due to failure to remove old sweat from
the skin surface, from allowing evaporation of some or all of the sweat
sample, thus concentrating the sample, or of an inappropriate collection.
Measuring potassium concentration in the sample may be helpful; if the
sample is above the normal range of 4-8 mmol l⁻¹, there is likely to be a
problem with the sample.

Interpretation of findings

The link between high sweat sodium losses and muscle cramps seems clear
in industrial settings, where a whole working day may be spent in hot and
humid conditions. Moss (1923) established that such cramps in coal miners
could be eliminated by addition of salt to drinking water. This is less certain in
sport, where sweat losses are generally smaller, but there is evidence that
individuals with high salt losses may be more prone to muscle cramps (Stofan
et al, 2005). Not all cramps are related to disturbances of electrolyte balance,
but it seems prudent to suggest that athletes prone to cramps may benefit
from increased intake of sodium before, during or after exercise. For those
with high salt losses, oral rehydration solutions intended for use of the
treatment of diarrhoeal disease may be effective: they typically have a sodium
concentration of 60-80 mmol l⁻¹ as opposed to the 20-25 mmol l⁻¹ found in
most sports drinks.

Salt losses in sweat may exceed 20-30 g per day when sweat losses are high:
this is far in excess of the upper limit of dietary intake recommended for those
at risk of hypertension, which is typically set at about 6 g per day. Athletes
with high salt losses may need encouragement to increase their dietary salt
intake. Some foods that are rich in sodium are shown in Table 2. Most highly
processed foods have a high salt content, and all will list the salt content on
the packaging.

Athlete feedback

Information to athletes is often couched in general terms: they are told to turn
up for events well hydrated, and may be told to drink a prescribed amount of
fluid during the event. This information is often unhelpful. Information provided
to athletes and coaches, and to medical and other support staff, must be
presented in such a way as to offer both a record of the data collected and
some constructive suggestions on any modifications required to current
hydration practice. Based on the measures described here, athletes can be
given some guidance as to whether their current hydration practices are
optimal and should be continued. If this is not the case, some specific
guidance as to the changes to be made can be given.

It is suggested that athlete feedback should consist of a single page of
information that includes a record of the date, environmental conditions and a
brief description of the training or exercise session. Information should be
presented in graphical form, with a short narrative description of each of the
measurements made. It might be appropriate to show data for: hydration
status, sweat loss volume, salt loss and fluid intake. Values for each should
be set in context and the athlete should be told whether their current hydration status and fluid intake are appropriate.

**Practical messages**

Although athletes often look to support staff to inform them of what they should do, there are several simple steps that they can take themselves to identify whether their current hydration practice is appropriate to their needs.

1. Athletes should be encouraged to weigh themselves before and after training sessions of different durations and intensities and in different weather conditions to estimate their sweat losses. Weight loss should generally not exceed about 1-2% of body mass. If more than this has been lost, then they probably did not drink enough and should drink more next time. If body mass loss was less than this, fluid intake was probably greater than was necessary for hydration purposes.

2. Any athlete who is passing urine less often than normal may be dehydrated. If urine volume is small and urine colour becomes darker, fluid intake should be increased. The aim should NOT be for urine to be as pale as possible.

3. Athletes should be encouraged to think about why and when they drink and relate this to the sweat loss and urine output they observe. If they drink whenever they are thirsty, but frequently seem to be dehydrated (according to assessments made) or they become significantly dehydrated during exercise, then their thirst stimulus may not be sufficient to drive an adequate intake. If, however, they frequently gain weight during exercise, when they seem to be well hydrated at the start of that exercise, or if they frequently urinate large volumes of very pale urine, then perhaps what they perceive as thirst is in fact hunger, a dry mouth or some other feeling.

4. “Salty sweaters” may need drinks with more salt and may need more salt in food when sweat losses are high. The use of salt tablets is seldom, if ever, warranted. Self-assessment of salt losses can be done by wearing a black T-shirt and looking for salt stains. High salt losses are a contributing factor in some cases of muscle cramp.

5. The athlete’s hydration strategy should take account not only of the amount of fluid that is required, but also of other nutrient needs such as carbohydrate and energy. Care should be taken to ensure that when large volumes of drink are consumed to meet hydration needs, the drink’s carbohydrate content is not such that the energy intake that accompanies intake exceeds the athlete’s energy budget. Diluting sports drinks with water will not necessarily provide a solution as this will dilute the electrolyte content.

**Summary**
Dehydration impairs both physical and mental performance, so fluid replacement strategies are necessary in exercise situations where large sweat losses occur. Some sodium should be added to drinks and/or to food when losses are high. Water and salt losses vary greatly, so individual prescription is required. Athletes should take responsibility for identifying their own rehydration strategy, which means assessing their own hydration status prior to exercise, assessing sweat rates and the adequacy of current drinking behaviour, and estimating the need for salt replacement.
References


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<tr>
<td>85.0</td>
<td>82.2</td>
<td>83.3</td>
<td>82.6</td>
</tr>
<tr>
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<tr>
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<td>94.1</td>
<td>93.1</td>
<td>92.2</td>
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<td>98.0</td>
<td>97.0</td>
</tr>
<tr>
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<td>102.9</td>
<td>101.9</td>
</tr>
<tr>
<td>110.0</td>
<td>108.9</td>
<td>107.8</td>
<td>106.7</td>
</tr>
</tbody>
</table>
Table 2  Foods with a high sodium content that might usefully be included in the diet when salt losses are high. The second column shows the amount of each item that must be consumed to replace the amount of sodium lost in 1 l of sweat with a sodium concentration of 50 mmol/l. Values are based on Holland et al (1991).

<table>
<thead>
<tr>
<th>Food item</th>
<th>Sodium (mg/100 g)</th>
<th>Amount of food (g) to replace 50 mmol of Na⁺</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bread (white)</td>
<td>520</td>
<td>221</td>
</tr>
<tr>
<td>Onion, pickled</td>
<td>450</td>
<td>255</td>
</tr>
<tr>
<td>Baked beans</td>
<td>530</td>
<td>217</td>
</tr>
<tr>
<td>Salmon, smoked</td>
<td>1880</td>
<td>61</td>
</tr>
<tr>
<td>Lamb curry</td>
<td>830</td>
<td>139</td>
</tr>
<tr>
<td>Sausage, grilled</td>
<td>1100</td>
<td>105</td>
</tr>
<tr>
<td>Bacon, fried</td>
<td>1910</td>
<td>60</td>
</tr>
<tr>
<td>Omelette, plain</td>
<td>1030</td>
<td>112</td>
</tr>
<tr>
<td>Cheese, Danish blue</td>
<td>1260</td>
<td>91</td>
</tr>
<tr>
<td>Pizza</td>
<td>570</td>
<td>202</td>
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<tr>
<td>Corn flakes</td>
<td>1110</td>
<td>104</td>
</tr>
<tr>
<td>Tomato juice</td>
<td>230</td>
<td>500</td>
</tr>
<tr>
<td>Potato crisps</td>
<td>1070</td>
<td>108</td>
</tr>
<tr>
<td>Peanuts, dry roasted</td>
<td>790</td>
<td>146</td>
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</tbody>
</table>