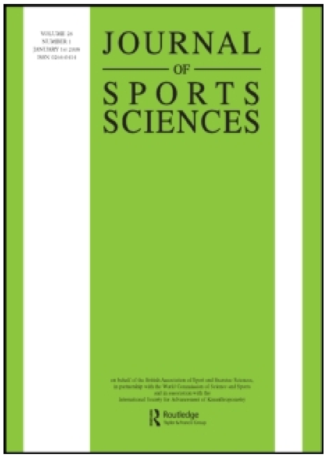

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Fluid needs for training and competition in athletics

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Abstract

The diverse nature of the athletic events, together with the varied training programmes and individuality of athletes taking part, inevitably means that fluid needs are highly variable – between athletes, perhaps between training and competition, and with differing environmental conditions and degree of training and heat acclimatization. There are limited data from athletics on all aspects of fluid balance, but wherever possible we have focused on this information to draw conclusions. When appropriate, euhydration will best be ensured by consuming 6–8 ml · kg body mass^{-1} of a sodium-containing fluid, or sodium-free fluid together with food, about 2 h before exercise. The individual sweat responses are so variable that athletes should assess their own individual sweat losses to determine if these are likely to be a cause for concern. The volume of drink that is consumed should never be so much that an athlete gains mass over an event, unless perhaps there is evidence that they began in a hypohydrated state. This may be a particular concern in the field events and multi-event disciplines when competition can be spread over a number of hours and when there are significant rest periods between activities.

Keywords: *Hydration, track and field, dehydration, rehydration*

Introduction

An in-depth discussion of the rationale and requirements for water and electrolyte intake before, during, and after exercise took place at the June 2003 International Olympic Committee Consensus Conference. The outcomes of the conference were published in the January 2004 issue of the *Journal of Sports Sciences*, with the papers by Coyle (2004) and Shirreffs and colleagues (Shirreffs, Armstrong, & Cheuvront, 2004) being particularly relevant. The information presented in these reviews will not be covered in depth again here, as there is no good evidence to suggest that the physiology or nutritional requirements of track and field athletes, with regard to their water and electrolyte requirements, differ significantly from those of other athletes in general. The focus of this review is new and updated material on these topics that has become available since the 2004 publication, and other pertinent material not covered in-depth in the two noted documents.

This review focuses on the water and electrolyte needs of adults who train and compete in athletic events. Where available, data from track and field athletes are presented and recommendations based on this information are proposed. The recommendations may be used by athletes and coaches to optimize performance and health, and by governing organizations that set the rules and regulations of the sport or the timing of events to guide their decisions. Other relevant recent publications on this topic include the updated Position Stand of the American College of Sports Medicine (2007) and information on individualizing fluid needs for athletes (Casa, 2004).

The 1995 IAAF Conference and the 2003 IOC Conference

The first IAAF Consensus Conference, held in 1995 (*Journal of Sport Sciences*, 1995), did not have a specific paper on hydration but the topic was covered with regard to both the young athlete (Bar-Or, 1995) and in general by Terrados and Maughan (1995). The 2003 IOC Consensus Conference concluded the following with regards to hydration in its consensus statement (IOC Consensus Statement, 2004):

> Dehydration impairs performance in most events, and athletes should be well hydrated before

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exercise. Sufficient fluid should be consumed during exercise to limit dehydration to less than about 2% of body mass... Sodium should be included when sweat losses are high, especially if exercise lasts more than about 2 h. Athletes should not drink so much that they gain weight during exercise. During recovery from exercise, rehydration should include replacement of both water and salts lost in sweat.

In addition, and specifically from the two recent international papers that covered the topic of hydration (Coyle, 2004; Shirreffs *et al.*, 2004), the following conclusions were drawn:

- A reduction in body mass of 2% is tolerable in temperatures up to 22°C but impairs absolute power production and predisposes athletes to heat illness in ambient temperatures above 30°C (Coyle, 2004).
- Sodium should be included in fluids consumed during exercise if the exercise lasts more than 2 h. It should also be included in fluids consumed by individuals in any event who lose more than 3–4 g of sodium in their sweat (Coyle, 2004).
- Normally before starting exercise euhydration should be ensured. Urine osmolality, specific gravity, and colour may be markers that can be used as a guide (Shirreffs *et al.*, 2004).
- After exercise that has resulted in body mass loss due to sweat loss, water and sodium should be consumed in quantities greater than those lost to optimize recovery of water and electrolyte balance (Shirreffs *et al.*, 2004).

The evidence on which these comments were based can be found within the papers.

Hydration for sprints

The duration of the sprint events (60 m flat and hurdles, 100 m flat and hurdles, 110 m hurdles, 200 m flat, and 400 m flat and hurdles) is clearly such that no hydration intervention is going to be made during the event itself, because by the time gastric emptying and intestinal absorption of any drink takes place, the event would have long finished (Vist & Maughan, 1994).

Sweat losses in sprinting

Maximum sweat rates reported in the published literature are typically in the order of 2–3 litres $\cdot$ h^{-1}. While there is no published data on sweat rates during single sprints, it is reasonable to assume that many athletes would have rates in the upper part of this range during or immediately after their sprint because of the intensity of the exercise. However, the duration of the exercise is such that even with very high sweat rates, the volume that would be lost during the event itself would still be relatively small. Therefore, the main concerns for hydration in sprint competition would be to ensure that any pre-race activities and warm-up procedures do not result in the athlete starting their competition in an undesirable hydration status; this obviously raises the question as to what an undesirable hydration status is and we attempt to address this issue below. Consideration must also be given to circumstances where a number of events or rounds are timetabled for the same day. In this case, the cumulative losses from a cycle of race preparation, race, recovery, race preparation, race, and recovery may quickly add up to a substantial sweat loss.

There appear to be no published data on the sweat losses that may occur during a typical training session of sprint athletes. However, Watson *et al.* (2005) monitored sweat volume losses in simulated sprint sessions in which the participants, who were experienced but not elite sprinters, warmed up for 15 min before (1) running a 50-m and 200-m sprint separated by 40 min or (2) undertook vertical jumps and a 400-m sprint. Each of these sessions was undertaken twice. The body mass reductions averaged 0.8 and 1.3 kg in the 50-m/200-m sessions over a 2-h period, and 0.5 kg and 1.1 kg in 45 min in the 400-m and vertical jump session. These reductions are equivalent to approximately 1–1.5% of the athletes' body mass.

Therefore, while sweat rates may be high with the high-intensity work of sprinting, the short duration of that work will limit the extent of sweat loss that occurs. The greatest sweat losses are likely to occur in training sessions of long duration, particularly in a warm environment or when warm clothing is worn, and in competitions where a number of rounds may be scheduled for the same day so that the cumulative sweat loss quickly adds up. In these circumstances, the athlete must be diligent regarding fluid replacement to ensure significant deficits in hydration status do not occur.

Effects of hydration status on sprinting performance

The influence of hydration status on sprint performance has been investigated in many studies using a number of different exercise modes. Although the majority of these have involved sprint cycling, in this review we restrict our discussion largely to studies of running sprints. It is possible that hypohydration may influence exercise performance differently depending upon whether the sprinting being investigated is running, where body mass must be supported and moved, or whether it is cycle ergometer sprinting, where this is not the case; if body mass is reduced, it changes the work required for the running. That is, the decreased body mass that is typically used to define the magnitude of hypohydration may compensate for any reduced muscular strength and/or power that it causes. However, while this will complicate the pure scientific interpretation of the findings of studies investigating sprint performance, it is what occurs in real athletic situations.

Watson *et al.* (2005) investigated the effects of hypohydration on both 50-m and 200-m sprint performance in experienced but non-elite sprinters. Mean body mass was reduced by 1.7 kg, $s = 0.4$ (equivalent to 2.2%, $s = 0.5$) by the administration of the diuretic furosemide. Watson and colleagues found no significant change in performance and reported a non-significant reduction in sprint time of 0.01 s ($s = 0.01$) in the 50-m event and of 0.26 s ($s = 0.22$) in the 200-m event. Fogelholm and colleagues (Fogelholm, Koskinen, Laasko, Rankinen, & Ruokonen, 1993) used a combination of fluid and energy restriction over a period of 59 h, followed by a 5-h *ad libitum* eating and drinking phase and an overnight fast, to reduce body mass overall by 2.0 kg, $s = 0.4$ (equivalent to 2.7%, $s = 5$), and then assessed the effects on 3 × 30-m sprint performance. The participants in this study were wrestlers and judokas, accustomed to this rapid body mass reduction, and the results indicated this had no significant effect on 30-m sprint performance, averaging 4.16 s ($s = 0.05$) after the body mass loss compared with 4.14 s ($s = 0.05$) in a control trial. Watson *et al.* (2005) also investigated the effects of hypohydration on 400-m sprint performance. Body mass was reduced by 1.9 kg, $s = 0.3$ (equivalent to 2.5%, $s = 0.4$), again by the administration of the diuretic furosemide. The authors found no significant change in 400-m sprint performance and reported a non-significant 0.33 s ($s = 0.58$) increase in sprint time. Taken together, the results of these studies suggest that body mass reductions of 2–3% have no significant effect on sprint performance. It is possible that sprinting would have been "easier" with the lower body mass, due to less mass for the runner to move. Thus, it is feasible that a reduction in physiological demand may promote improved performance, which may counteract any effects hypohydration has on sprinting.

Hydration strategies for sprinting

From the limited evidence available, it would appear that track sprinting performance is not affected by hydration status at least when body mass is reduced in the order of 2–3%. These athletes should therefore be advised to ensure that they start any sprint session (training or competition) in a state of euhydration or with no more than a 2–3% body mass reduction that is due to water loss. An athlete's euhydration is best ensured by consuming a 500-ml bolus (or $6-8\ \text{ml} \cdot \text{kg body mass}^{-1}$) of fluid containing sodium, or a sodium-free fluid together with solid food, approximately 2 h before their sprint. Water required by the body will be retained and excess will be excreted as urine over the 2-h period.

Recovery of body water losses after sprinting will be a major consideration only when a large body water deficit has developed, particularly when further sprinting is scheduled. A sufficient volume of fluid should be consumed to replace not only the sweat losses that have occurred, but also to provide for the ongoing obligatory urine losses and potential further skin losses, which occur in particular if the athlete is in a warm environment (Shirreffs, Taylor, Leiper, & Maughan, 1996).

Hydration for middle-distance running

The middle distance events of 800 m up to and including the 3-km events can range in duration from less than 2 min to close to 9 min in elite athletes. The brief duration of these races ensures that, like the sprint events, there is no practical opportunity for a hydration intervention during the event itself – by the time gastric emptying and intestinal absorption of any drink takes place, the event would have finished (Vist & Maughan, 1994).

Sweat losses in middle-distance running

The environmental conditions, an athlete's individual characteristics (including the extent to which any heat acclimation has taken place), together with the duration and intensity of exercise will influence the sweat loss that occurs in middle-distance running. The variability between individuals performing the same exercise in identical conditions can be so extensive (Shirreffs, Sawka, & Stone, 2006) that reporting mean values from laboratory or field studies of middle-distance running events does not provide unique insights about the values estimated from generic sports activities of similar exercise durations. In middle-distance running events, as for the sprints discussed above, the sweat volume lost will be relatively small because of the short duration of the events.

The training undertaken by middle-distance athletes generally includes a significant endurance and interval component. Therefore, because of the duration and/or the intensity of running involved, significant sweat losses are likely to occur.

Effects of hydration status on middle-distance running performance

A limited amount of research has been undertaken to investigate the influence of hydration status on middle-distance running performance. However, some time ago, Armstrong and colleagues (Armstrong, Costill, & Fink, 1985) studied the influence of hydration status in track races over 1.5, 5, and 10 km. Volunteers completed these races twice: once in a euhydrated state and once after reducing their body mass by 1.4 kg, $s = 0.3$ (equivalent to 1.9%, $s = 0.4$) using the diuretic furosemide. The time to complete these races was increased by 0.16 min ($s = 0.19$), 1.31 min ($s = 0.73$), and 2.6 min ($s = 1.66$) respectively [equivalent to 3.1% ($s = 3.5$), 6.7% ($s = 3.4$), and 6.3% ($s = 3.9$) respectively], relative to their finishing time when euhydrated.

Hydration strategies for middle-distance running

From the limited evidence available, it would appear that in middle-distance events, at least those longer than 1.5 km, performance can be negatively affected by a loss of body water equivalent to 2% body mass. Middle-distance athletes should therefore be advised to start any middle-distance event in a state of euhydration, or at least to limit any body water loss prior to exercise to less than 2% body mass. Euhydration may best be ensured using the same practices as described above for sprinting. The influence of ambient conditions, particularly temperature, on the interaction between hydration status and performance in the middle-distance events has not been studied systematically. Also, studies of these events across a range of ambient conditions are too few to allow any conclusions to be drawn about the interactions of body water loss, ambient conditions, and performance in middle-distance events in the way they have been for the distance events (see below). As for sprinting, recovery of body water losses after a middle-distance event will be a major consideration only when a large body water deficit has developed, especially when further exercise is scheduled. Again a sufficient volume of fluid should be consumed to ensure it is enough to replace the ongoing water losses (Shirreffs *et al.*, 1996).

During training for middle-distance events, when the duration and/or intensity of exercise may result in significant body water losses, drinking should be considered when an athlete knows their sweat rate will lead to a significant body water deficit over the course of the session and also when a significant portion of the training has yet to take place once this has developed. This is particularly important in the case of a high-quality training session involving a "performance" element. Drinks that are consumed for the purpose of influencing hydration during a session should be emptied from the stomach and be absorbed in the intestine relatively quickly.

Recovery of body water losses after training for middle-distance running will be a major consideration only when a large body water deficit has developed and when further training is scheduled for the relatively near future. Given the endurance and interval training frequently undertaken by middle-distance athletes, the volumes of sweat that may be lost and the likelihood that drinking during training may frequently be limited for logistical or stomach comfort reasons, this will not be an uncommon scenario. In addition to consuming a sufficient volume of fluid to replace all ongoing water losses (Shirreffs *et al.*, 1996), sodium should also be consumed at this time if the fluid is to be retained in the body (Shirreffs & Maughan, 1998). This sodium could be an ingredient of the drink selected or it may come from solid food consumed with the drink (Maughan, Leiper, & Shirreffs, 1996; Ray *et al.*, 1998).

Hydration for distance events

The distance events are longer than 3 km and include both running events and the walks. Compared with the other athletics events, there has been a considerable amount of both descriptive research into sweat losses of athletes during some distance events (in particular the marathon) and also intervention studies investigating the effects of hydration status, and particularly body water loss, on aspects of endurance exercise performance. However, in the shortest of these distance events there is likely to be little benefit of drinking during the exercise because of the time required for gastric emptying and intestinal absorption to occur.

Sweat losses in distance running and walking

The extent of sweat losses in distance events is influenced by environmental conditions, an athlete's individual characteristics (including the extent to which any heat acclimation has taken place), and the duration and intensity of the exercise. Again the variability of sweat rates between individuals performing the same exercise in identical conditions can be so extensive (Shirreffs *et al.*, 2006) that reporting mean values from distance running events assessed either in the laboratory or in field studies provides little specific insight. Nevertheless, with normal sweat rates being anything up to 2 – 3 litres per hour, and the longest of the championship distance events (the 50-km walk) lasting more than 3.5 h for elite athletes, it is clear that significant sweat losses can occur. All distance athletes should assess their own sweat rates so they have an understanding of their response to both their training and competition runs in a variety of environmental conditions.

It is clear from the published literature that significant sweat losses do occur in marathon runners. As described in detail by Coyle (2004), the findings of Cheuvront and colleagues (Cheuvront, 2001; Cheuvront, Carter, & Sawka, 2003; Cheuvront & Haymes, 2001; Cheuvront, Montain, & Sawka, 2007) show that many fast marathon runners experience significant body mass loss over the course of the marathon, with values ranging from 2 to 8% body mass loss by the end of the race.

Effects of hydration status on distance running and walking performance

Cheuvront *et al.* (2003) have recently published an excellent review of the literature on fluid balance and endurance exercise performance, with protocols ranging in duration from 1 to 6 h. However, even though only one of the 13 evaluated studies involved running as the sole mode of exercise, this is probably the best available data set to draw any reliable conclusions as to the effect of hydration status on endurance running and walking performance. It is important to bear in mind the influence a lower body mass has on the physiological demands of running as discussed above.

In their review, Cheuvront *et al.* (2003) conclude that dehydration equivalent to between 2% and 7% of body mass loss significantly reduces exercise performance and this is particularly true in hot environmental conditions (i.e. hotter than 30°C). There are no data to indicate what happens with reductions in body mass of more than 7%, but there is no reason to suspect it will improve performance. The authors also concluded that dehydration equivalent to a body mass reduction of between 1 and 2% did not influence endurance exercise performance when the exercise duration was less than 90 min and the environmental conditions were temperate (20–21°C). In contrast, if the dehydration was equivalent to a body mass loss of more than 2%, endurance performance was impaired in these temperate conditions especially if the exercise lasted more than 90 min.

Hydration strategies for distance running and walking

Because of the large variations between athletes and the different distance running and walking events, general guidelines will be meaningless for many individuals. However, from the evidence available it appears that distance exercise performance is likely to be impaired with a body water loss equivalent to 2% or more of body mass in both temperate and warm environmental conditions. These athletes should therefore be advised to ensure that they start any distance walk or run in a euhydrated state. Euhydration may best be ensured using the same practices as described above. The influence of ambient conditions, particularly temperature, on the interaction between hydration status and distance events means that extra care to limit the development of hypohydration must be taken when the environmental conditions are hot.

During the longer distance events, provision is made to allow athletes to obtain drinks. When athletes can select the composition of the drink they consume, they should consider how much they expect to sweat during the event to address both volume and sodium losses. During the event, replacement of sweat volume and sodium losses are not going to be the only nutritional concern of the athlete, but in events where this is the major concern or at the specific times when it is in other events, the drink selected should be emptied from the stomach and be absorbed in the intestine relatively quickly. This means that the drink should not have a high energy density or osmolality. Ideally, it should probably be hypotonic with respect to the body fluids, in the range $200-260\ \text{mOsmol}\cdot\text{kg}^{-1}$ (Leiper, 2001), and perhaps contain sodium and glucose at concentrations of about $30-50\ \text{mmol}\cdot\text{l}^{-1}$ and no more than $200\ \text{mmol}\cdot\text{l}^{-1}$ respectively to promote rapid intestinal absorption (Leiper, 2001). In some of the longer distance events, where solid food is favoured at intervals by the athletes, water or sodium-free drinks consumed at those times will still meet these requirements. Of course, in some circumstances, distance runners and walkers choose the characteristics of fluid consumed during an event based on the desire to address fuel needs rather than optimal hydration concerns (see Burke, Millet, & Tarnopolsky, 2007).

Recovery of body water losses after either distance training or competition will be a major consideration when either a very large body water deficit has developed or when it is more moderate but when further training is scheduled for the relatively near future. As described previously, rehydration strategies should address the volume of fluids consumed and the replacement of sodium losses (Shirreffs & Maughan, 1998; Shirreffs *et al.*, 1996).

Hydration for jumps and throws

The jumps events include the long jump, triple jump, high jump, and pole vault. The throws events include the shot put, hammer throw, discus throw, and javelin throw. None of these field events appear to have been subject to systematic study with regard to any aspect of hydration.

There are perhaps more similarities in the training and competition for the throws and jumps events than there are in many other athletic events. During both training and competition, there are periods of intense activity and periods of little activity: in training these may be rest breaks, in competition these are breaks between rounds. Therefore, during both training and competition, the period in the field can last several hours.

Sweat losses in the jumping and throwing events

As with other athletes, the sweat losses that occur in jumpers and throwers will be determined by the athlete's individual characteristics, the environmental conditions, the time spent in the field, and the intensity of exercise itself. However, as many athletic events are performed in warm conditions, the sheer length of time spent in the field, even though no exercise is being performed, can have a great impact on the sweat losses that occur.

The lack of data on "typical" sweat losses of jumpers and throwers again is of little consequence given the variability that would be predicted to occur between individual athletes (Shirreffs *et al.*, 2006). Therefore, all jumps and throws athletes should be encouraged to assess their own sweat losses in a variety of exercise scenarios and so understand their own sweating response to their training and competition.

Effects of hydration status on the jumping and throwing events

There appear to be no published studies that have systematically evaluated the influence of hydration status or sweat loss on the performance of any of the athletic jumping and throwing events. Therefore, any conclusions must be drawn from information from related sources.

Jumping performance has frequently been investigated as a means of assessing the influence of body water loss on muscle power; jump power and jump height have most often been measured (e.g. Gutiérrez, Mesa, Ruiz, Chirosa, & Castillo, 2003; Hoffman, Stavsky, & Falk, 1995; Kraemer *et al.*, 2001; Viitasalo, Kyrolainen, Bosco, & Alen, 1987; Watson *et al.*, 2005). In most of these studies, the body mass loss was between 1 and 3% (Gutiérrez *et al.*, 2003; Hoffman *et al.*, 1995; Watson *et al.*, 2005), although a 6% body mass loss was evaluated when energy restriction was combined with dehydration (Kraemer *et al.*, 2001; Viitasalo *et al.*, 1987). Most of these studies found no significant effect of the body mass reduction on jumping power or height. As discussed above with sprinting, jumping will also become "easier" as hypohydration progresses since the jumper has to move less mass. Therefore, it is possible that if any negative effects of hypohydration on jumping performance exist, they might be masked by the decrease in physiological demand and the improved performance achieved by a loss of body mass. Furthermore, if hypohydration does not reduce muscle force or power, jumping performance may be improved with hypohydration. However, systematic research is required to investigate this.

For throwing events, any effects hypohydration may have could be gleaned from research investigating muscle strength and power or from studies where other types of throwing have been studied. For example, in a study investigating the motor skill performance of cricket bowling (Devlin, Fraser, Barras, & Hawley, 2001), participants were dehydrated by 2.5 kg, $s = 0.6$ (equivalent to 2.8%, $s = 0.5$, of their body mass), and their performance was compared to that when they had drunk flavoured water and limited their dehydration to 0.5 kg, $s = 0.5$ (equivalent to 0.5%, $s = 0.4$, of their body mass). The results of the study indicated that there was no influence of hydration status on bowling speed, but bowling accuracy, as determined by line and distance, was significantly worse when undertaken in the dehydrated state. It is, however, the bowling speed that is more relevant to the throwing events in athletics.

Hydration strategies for jumping and throwing events

Although the breaks in training or between jumps and throws in competition prolong the "exercise" period, and thus in warm environmental conditions will increase the sweat losses that occur, these breaks also generally provide ample opportunity for drinking to take place. For this reason, it is essential that each athlete understands their own individual sweat losses and fluid requirements. At present, there are too few data to determine if there is a level of dehydration that negatively effects performance in the jumps and throws, so the best advice to athletes may be for them to try to maintain their hydration status to somewhere between euhydration and 2% of their body mass loss. Some care must be taken by these athletes, particularly the jumpers, to ensure that they do not "overdrink" during the long hours they may spend in the field. Although they are not likely to do this to the extent that they will have any health concerns, there is anecdotal evidence that some may tend to do so to a limited extent. In the same way that a reduction in body mass reduces the work of jumping, an increase in body mass will increase the work and unnecessary unchecked drinking may be enough to increase body mass by a kilogram or more over a number of hours if sweating rate is not high and drinks are freely available. This may, in theory at least, have a negative impact on performance.

Hydration for multi-events

The multi-events of pentathlon, heptathlon, and decathlon combine events from all the categories discussed above with the exception of the endurance events. There appear to have been no studies investigating the effects of hydration status on multi-events, and there have been no descriptive studies of the effects of training or competing in the multi-events on any aspect of hydration. This includes descriptions of the typical sweat losses that may occur and the effects a change in hydration status or a body water loss may have on the events.

Competition in these events generally takes place over a period of one or two days and it is reasonable to expect that sweat losses may be high as a result of the repeated bouts of exercise. However, there are also repeated rest periods throughout the competition time: between events and between jumps and throws in the field events. These breaks should provide ample opportunity for fluid intake sufficient to keep body water loss close to a euhydrated state (perhaps between euhydration and a body mass loss of 2%) for the majority of athletes.

Athletes who compete in these events will have training programmes that encompass the types of training undertaken by athletes competing in the individual events that make up these multi-events. As such, the sweat losses are likely to vary with the type of training that is being undertaken.

Multi-sport athletes would normally be advised to ensure that they start any training session or competition event in a euhydrated state. As reported above, euhydration may best be ensured by consuming a 500-ml bolus (or $6-8$ ml · kg body mass^{-1}) of fluid containing sodium, or sodium-free fluid together with solid food, approximately 2 h before their exercise. Water required by the body will be retained and the excess excreted as urine over the 2-h period.

When a multi-event athlete expects their sweat losses to become significant during training or competition, they should ensure they have a supply of the drink or drinks of their choice with them through the training or competition day. When drinking for hydration reasons and sweat losses are high, it may be cautious to ensure some of the drink available for consumption has a formula appropriate to promote rapid assimilation into the body. Again, this means that the drink should not have a high energy density or osmolality and ideally should be hypotonic with respect to the body fluids. If an athlete knows their sweat sodium losses are high, they should also ensure they have a drink containing sodium, or easily consumed foods that provide sodium.

Recovery of body water losses after the first day of a multi-event competition may be a recovery priority for many of these athletes. Again, a sufficient volume of fluid should be consumed to replace not only the sweat losses that have occurred but also to provide for the ongoing obligatory urine losses and potential further skin losses, which can occur especially if the athlete is in a warm environment (Shirreffs *et al.*, 1996). Sufficient sodium should also be consumed with this fluid to replace the sweat sodium losses (Shirreffs & Maughan, 1998).

Hydration considerations for mental and cognitive readiness

One of the deleterious effects of moderate or severe dehydration is reductions in cognitive function, mental readiness, reaction time, and motor control. However, mild dehydration, defined as $1-2\%$ loss of body mass, has not been shown to be associated with mental function decrements or reduced reaction time (Leibowitz, Abernethy, Buskirk, Bar-Or, & Hennessy, 1972). Edwards *et al.* (2007) assessed whether moderate water loss ($1.5-2\%$ of body mass loss) results in significant impairment on mental concentration tests. They showed that moderate dehydration did not impair mental concentration.

Furthermore, global cognitive readiness and decision making are preserved during water deprivation, up to moderate dehydration of 2.6% of body mass, without severe hot weather conditions and intense exercise (Szinnai, Schachinger, Arnaud, Linder, & Keller, 2005). Szinnai and colleagues assessed whether mental performance is affected by slowly progressive moderate dehydration induced by water deprivation. They demonstrated that cognitive-motor function is preserved during water deprivation in young healthy humans up to a moderate dehydration of 2.6% of body mass. However, increased tiredness and reduced alertness may be consequences of prolonged moderate dehydration. Similar experiments were conducted by Petri and colleagues in a study that assessed if there is deterioration in mental and psychomotor performance during voluntary fluid intake deprivation for 24 h (Petri, Dropulic, & Kardum, 2006). During the dehydration period, there was no significant deterioration in mood self-estimate scales and subjective measures of mental status. Taken together, these data suggest that mild to moderate dehydration, without adverse heat stress, is unlikely to be associated with reductions in cognitive function, mood, and mental readiness. However, this level of dehydration may be approaching the limits of compensatory mechanisms to preserve alertness and mood status.

After short-term exercise or heat-induced dehydration, decrements in cognitive aptitude have been observed in normal healthy individuals at a moderate dehydration of 2.5% or more of body mass (Cian *et al.*, 2000; Cian, Barraud, Melin, & Raphel, 2001; Sharma, Sridharan, Pichan, & Panwar, 1986). Cian *et al.* (2001) reported an initial drop in short-term memory immediately after acute exercise-induced dehydration (2.8% body mass loss) that returned to baseline values within 3.5 h independent of water intake. Decrements in mental function have also been reported during longer exercise durations in the heat (Ekbolm, Greenleaf, Greenleaf, & Hermansen, 1970).

Dehydration (>3% of body mass losses) will likely have a negative effect on cognition, mood, and mental status during exercise and at rest (Cian *et al.*, 2000). The reduction in performance and mental readiness is proportionate to the degree of dehydration beyond 3% of body mass losses. In addition, during events of longer duration, dehydration is one of several stressors that contributes to decrements in exercise performance (Doppelmayr, Finkernagel, & Doppelmayr, 2005). Thus, athletes should limit dehydration to less than 2.5% body mass losses to preserve alertness and cognition function at all times, in particular during days with high ambient temperatures.

Summary of recommendations for fluid intake for track and field athletes

Consensus for:

- Euhydration may best be optimized by consuming a 500-ml bolus (or 6–8 ml·kg body mass^{-1}) of a fluid containing sodium, or a sodium-free fluid together with solid food, approximately 2 h before exercise. Water required by the body will be retained and the excess excreted as urine over the 2-h period.
- Individual sweat responses to exercise are so variable that each athletes should assess their own individual sweat losses to determine if these are likely to be a cause for concern.
  - This applies to athletes in all events.
  - Ideally this would be repeated in a variety of the athlete's regular training and competition scenarios so that their "normal" response in these conditions can be established.
- In events where body mass must be carried, care should be taken to avoid overdrinking. The drink volume consumed should never be so much that an athlete gains mass over the course of an event, unless perhaps there is evidence that they started the event in a hypohydrated state.
  - This may be a particular concern in the field events and multi-events when competition is spread over a number of hours and when there are significant rest periods between periods of activity.

Consensus against:

- The thoughtless following of general recommendations of the volumes of fluid consumed should be discouraged, as it so easy for athletes to assess their own drinking requirements to ensure hydration.

Issues that are equivocal:

- The influence of hydration status, and in particular hypohydration, has not been systematically studied in many athletic events. If this research were to be undertaken, it would assist in the making of recommendations. Additionally, the additive influence of exercise in the heat while hypohydrated must be assessed for a multitude of athletic events.

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