DISCUSSION DOCUMENT: GUIDELINES FOR FLUID REPLACEMENT DURING MARATHON RUNNING. November 2001 Lecture to IMMDA members

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Prior to 1969, marathon runners were advised against drinking or eating during competition (1) since it was believed that, especially fluid ingestion would impair performance, not least by causing unpleasant gastrointestinal symptoms including the “stitch”. At that time, marathon runners and marathon races were quite different from their modern descendants. In particular, there were few competitive marathon runners; most were well trained, usually completing marathon races in less than 3-3½ hours. As a result, most marathon races were small, with fields of a few hundred runners at most. Races usually closed after 3½ hours and little if any, medical care was provided, presumably because there was little need. Indeed the first reports detailing the nature of the medical care provided at specific marathon races were published only in the 1980's (2).

However, the introduction of the Big City marathons, beginning with the 1976 New York City Marathon, substantially altered the number and hence the type of athlete entering marathons and consequently the nature of the sport itself. First, the numbers of runners in these races increased exponentially at least for the first 10 years, producing a number of races in which tens of thousands of runners competed. Second, the average finishing time of runners in these much larger fields has increased by at least 60 minutes, indicating that the “average” marathon runner of the early 2000’s is quite different from the “average” runner competing in marathon races even 25 years ago. Thus the “average” modern marathon runner runs slower either because he or she is a genetically less-good athlete or because he or she trains less intensively, or perhaps both. Third, there has been an exponential growth in the extent of the medical support provided before, during and after these races. Fourth, the approach to drinking before, during and after the race is the diametric opposite to that which was advocated in the 1960’s. Thus the current paradigm is that athletes should drink “as much as possible" during any form of exercise but especially during marathon running (3-6).

Background to this document.

The recent acceptance that athletes can drink too much during prolonged exercise with potentially fatal consequences (7-14), indicates that the guidelines for fluid replacement especially in the military (12,13) but also during more prolonged exercise like marathon running, require urgent revision.

A careful review of the guidelines of the American College of Sports Medicine for fluid replacement during exercise (3-6) indicates that they are not evidence-based (15,16). Rather they appear to have been formulated specifically to support only one interpretation, namely the need for athletes to drink "as much as possible" during exercise. Since a body of evidence exists to show that this advice can be harmful especially if practiced by marathon runners who take 5 or more hours to complete marathon races (7-9), the medical directors of marathon races should not expect legal protection simply because they followed those guidelines and advised athletes competing in races under their jurisdiction to drink "as much as possible". It is this finding which has encouraged a revision of the popular advice provided to athletes competing in those modern marathon races in which a significant number of entrants may require 5 or more hours to complete the distance.

This document is presented as a focus for debate for medical directors of marathon races. It is hoped that a consensus document might be agreed upon at the meeting of marathon medical directors to be held in New York, the day before the 2001 New York City Marathon.

Traditional arguments for why athletes should drink "as much as possible" during prolonged exercise.

Beginning in 1969, a series of studies was published which showed a relationship between the levels of dehydration that developed during exercise and the rise in rectal (core body) temperature (17-21). This led to the conclusion that dehydration was the single greatest risk to the health of marathon runners since it would cause the body temperature to rise, leading to heat illness, including heatstroke (4-6,16-18). A related conclusion was that marathon runners who collapsed during or after races are suffering from dehydration-induced heat illness, the urgent treatment for which must be rapid intravenous fluid therapy (22).

Furthermore laboratory studies which, in retrospect, were performed in environmental conditions exceeding those under which marathon races may be sanctioned, showed that the complete repletion of fluid losses during exercise maintained more normal cardiovascular function and lower rectal temperatures than did lesser levels of fluid replacement during exercise (20-21). Hence it was concluded that the complete replacement of fluid losses during exercise was desirable so that all athletes should be encouraged to drink "as much as possible" during exercise (4-6).

Arguments against the advice that you should drink "as much as possible" during exercise.

The most compelling argument against this advice has been the dramatic rise in the number of endurance athletes suffering from fluid overload in marathon and ultramarathon races (Table 1). Thus more than 70 cases of this condition have been described (7-9) since the condition was first recognized in 1985 (23). The majority of these cases occur in athletes in the United States and many report that they followed the usual advice that they should drink "as much as possible" during exercise (9). During the same time period, it has been difficult to find even one publication in which dehydration has been identified as the sole important causative factor for even a single case of exercise-related heatstroke.

Hence the conclusion must be that the advice to “drink as much as possible” during prolonged exercise has generated an iatrogenic disease, the incidence of which has increased sharply in the past 15 years during the same period that the ACSM guidelines (3-6) have been propagated with increasing enthusiasm. Furthermore it appears that the medical risks associated with this novel iatrogenic condition exceed the risks associated with the condition for the prevention of which this (harmful) advice was originally formulated. This is particularly unfortunate since there is no credible evidence that high rates of fluid ingestion can influence the risk of heatstroke (22,24,25).

Second, there is no evidence that this advice has reduced the number of people seeking medical care after marathon and ultramarathon races. Indeed some have found that the advocation of a conservative drinking policy is associated with fewer than expected admissions to the race day medical facilities, not least because the incidence of water intoxication is substantially reduced (26,27).

Third, there are significant questions about the practical relevance of the original laboratory and other studies which form the scientific foundation for the advice to drink “as much as possible” during exercise (18-21). In particular, most of those studies were performed in environmental conditions that exceed both the guidelines for safe exercise proposed by the American College of Sports Medicine and the conditions under which marathon directors would be happy to allow races to proceed under their jurisdiction. In addition, many of these studies were performed without adequate convective cooling (16) (facing windspeed), which is an important difference when exercise is performed either in the laboratory or out-of-doors (28). Inadequate convective cooling might explain why the relationship between increasing levels of dehydration and an elevated body temperature, detected in laboratory studies performed under these inappropriate environmental conditions, has never been confirmed in out-of-doors competitive sport (26,27,29,30). Indeed the logical conclusion from those other studies is that, when subjects are allowed to choose their own pacing strategies as they do when participating in out-of-doors competitive sport, then the level of dehydration, and hence the drinking behaviour of the athletes, becomes a relatively unimportant determinant of the rectal temperature during exercise.

Fourth, there are no studies showing that dehydration or its prevention plays any role in the cause or prevention of the so-called “heat illnesses” that are frequently diagnosed, on questionable grounds, in athletes seeking medical care after endurance events (22,24,25). Rather it has been suggested that postural hypotension, reversible by nursing the collapsed athlete in the head-down position (25,31-33), is the most appropriate and only necessary form of treatment for these incorrectly diagnosed as cases of “heat illnesses”.

Fifth, there is no exact certainty of how to determine the level of dehydration that develops, especially during prolonged exercise like marathon running. This is because the level of dehydration cannot be determined simply as the extent of the weight loss during exercise. For the reason that the weight lost during exercise comprises up to 1kg of metabolic fuel that is irreversibly oxidized during exercise and a variable amount of fluid that is stored with glycogen and released during exercise as the stored liver and muscle glycogen stores are oxidized. It has been calculated that an athlete who loses 2kg of weight during a marathon race would, in fact, be dehydrated by only ~200g (34) when allowance is made for the weight lost from those other sources. Interestingly, the average weight loss during marathon races in which athletes drink “ad libitum” and not “as much as possible”, is between 2-3 kg suggesting that most athletes accurately assess their needs for fluid replacement during exercise. This contrasts to the currently popular dogma which holds that thirst is an inaccurate index of the fluid requirements during exercise so that athletes must drink to a predetermined formula and not in response to thirst during exercise. It is argued that athletes who drink only in response to their thirst will become sufficiently dehydrated during exercise that their performances will be impaired and their health placed at risk. Hence they are required to drink “as much as possible”.

Sixth, empirical evidence suggests that world-class runners ingest very little fluid during competitive races, in part because of the difficulty of ingesting fluid when running at the high exercise intensities (~85% of maximum oxygen consumption) and running speeds (~ 20 km per hour; 12.5 miles per hour) necessary to achieve success in those races. Personal discussions with elite African marathon runners suggest that they ingest about 200ml per hour during marathon races; a figure not strikingly different from amounts reported in the 1960’s in slightly less good athletes (17,35,36), but substantially less than the volumes of 1.2 - 2 liters per hour that the ACSM guidelines recommend for elite athletes in competition. This finding alone disproves the dogma that only by drinking “as much as possible” will athletes be able to perform at a world class level.

SPECIFIC GUIDELINES

1. *The true incidence of the real heat illnesses in marathon runners is unknown but appears to be extremely low.*

True heatstroke (diagnosed as a rectal temperature in excess of 40-41oC in an athlete who shows an altered level of consciousness without other cause, and who recovers only after a period of active cooling) is an extremely uncommon complication of marathon running. For example, Roberts (37) reported that in the first 25 years of the Twin Cities Marathon, there were less than XXXXX cases of heatstroke. Whilst there are no similar data for other races, there is not reason to believe that these findings are not similar to those from other marathon races around the world.

Indeed it is for this reason that anecdotes – Jim Peters in the 1954 Empire Games Marathon; Alberto Salazar in the 1982 Boston Marathon; XXXX in the 1984 Olympic Games Marathon - are frequently used to project the danger of heatstroke during marathon running (36) and hence the need to drink adequately to prevent this condition in marathon races. In fact these anecdotes really only prove how extremely rare is this condition in modern marathon races run in reasonable environmental conditions.

2. *On the other hand, the number of athletes requiring medical care especially after marathon races has increased precipitously in the past 25 years, as evidenced by the growth in the provision of medical services at those races.*

However there is no evidence that the vast majority (> 99%) of the athletes treated in those medical facilities are suffering from heat-related illnesses since (i) they recover without active cooling and (ii) their rectal temperatures are not higher than are those of control runners who do not require medical care after those races (37-40).

It is our opinion that a diagnosis of heat illness should be reserved only for those patients who have clear evidence of heatstroke, the diagnostic symptoms of which are described above, and the successful treatment of which requires active whole body cooling. If the rectal temperature is not elevated above 40 – 41oC, then a diagnosis of “heat illness” cannot be sustained and an alternate diagnosis must be entertained (25,32). Much of the confusion of the role of fluid balance in the prevention of heat illness indeed arises because of the adoption of incorrect diagnostic categories for the classification of “heat illnesses” (16,25,32).

3. The crucial factors that determine the risk of heatstroke are ***not the levels of dehydration reached during exercise*** *but rather* ***the rate at which the athlete produces heat and the capacity of the environment to absorb that heat****.*

Perhaps the main reason why an incorrect doctrine (that dehydration alone causes heatstroke) has achieved universal credence is because those who have been the most vocal in promoting the doctrine, appear to be ignorant of the multi-factorial aetiology of heatstroke and, especially, the relative importance of the different aetiological factors.

For the simple reality is that heatstroke can only occur when the athlete's rate of heat production exceeds the rate at which the excess heat produced during exercise can be dissipated into the environment. More importantly, there are many factors much more important than dehydration, which determine when the rate of heat production exceeds the rate of heat loss.

The rate of heat production is determined by the athlete's rate of energy expenditure (metabolic rate), which is a function of the athlete's mass and intensity of effort (running speed). Note that heavier athletes and those who exercise at a faster running speed will generate the higher metabolic rates and hence are at greater risk of heat injury during exercise (41). According to this logic, the risk of heatstroke will be greatest in athletes who run faster for example during 10 km races (42) than when they run slower, for example, in 42 km races. Since they generate more heat when running at the same speed, heavier athletes will also be at greater risk than lighter athletes when both run at the same speed (41). In addition, heavier athletes will have a much greater difficultly losing heat when exercising in the heat than will smaller runners (41).

The capacity of the environment to absorb the heat generated by the athlete during exercise is determined by the environmental temperature and humidity, and by the rate at which the surrounding air courses over the athlete's body, producing cooling by convective heat losses.

The result is that the risk of heatstroke is increased:

- when the exercise intensity is highest, for example in short distance races rather than in longer distance races including the marathon (most especially in those who take 5 or more hours to walk/run the distance) when the running/walking speed and hence the rate of heat production is lower;
- in heavier athletes who generate more heat than do lighter athletes when running at the same speed;
- when the environmental temperature but most especially the humidity of the air is increased;
- when the potential for convective cooling is low as occurs under wind still conditions or in laboratory experiments in which there is inadequate convective cooling (16,28).

As a result the prevention of heatstroke in distance running requires that attention first be paid to those factors that really do contribute to the condition in a meaningful way, much as the prevention of any medical condition requires that more attention be paid to the crucially important aetiological factors, rather than to those factors that are of relatively lesser consequence.

Thus in the context of the prevention of heatstroke, the most important aetiological factors that require to be addressed are:

- the intensity of effort and hence the metabolic rate that the athletes will sustain. Thus greater efforts at prevention are required in short races run at higher speeds than in long distance races, run at slower speeds;
- the size of the athletes since heavier athletes are at greater risk if they are able to sustain the same high running speeds as are lighter runners;

- the environmental conditions most especially the humidity since it is the humidity which affects heat loss via sweating which is the most importance source of heat loss in runners.

Encouraging slow runners/walkers in marathon races to drink "as much as possible" is the incorrect treatment for the wrong group of athletes, since it is precisely that group of athletes who are at essentially no risk of developing heatstroke since their rate of heat production during exercise is so low. But as has already been noted, the elite athletes at risk of heatstroke drink very little during these races. They are able to do this because they select to run in races in which the environmental conditions are such that it is safe for these (very small) runners to compete at a very high intensity without risking the development of heatstroke, whether or not they drink during those races.

4. *In the absence of a diagnosis of heatstroke or other obvious medical conditions, the vast majority of athletes who collapse <u>after</u> finishing the marathon race are likely to be suffering from the rapid onset of postural hypotension. Diagnosing this condition as a "heat illness" is intellectually harmful not least because it creates the harmful doctrine that "**if only these athletes had drunk 'as much as possible' during the marathon, they would not have required medical care after the race**".*

A crucial recent finding was that the majority (~ 75%) of athletes seeking medical care at marathon or ultra marathon races collapse only **after** they cross the finishing line (32,40). It is difficult to believe that a condition insufficiently serious to prevent the athlete from finishing the race, suddenly becomes life-threatening only after the athlete has completed the race, at the very time when the athlete's physiology is returning to a state of rest. Rather, the evidence is that athletes who collapse **before** the race finish are likely to be suffering from a serious medical condition for which they require urgent and expert medical care (32,40).

Our conclusion is that athlete who collapse and require medical attention **after** completing long distance running events are suffering from the sudden onset of a postural hypotension (31,32). There is no published evidence that this postural hypotension is due to dehydration. Nor does logic suggest this to be likely since dehydration should cause collapse when the cardiovascular system is under the greatest stress for example, during rather than immediately on the cessation of prolonged exercise.

Rather, the hypotension is likely to be due to the persistence of a state of low peripheral vascular resistance into the recovery period, compounded by the absence, as soon as the athlete complete the race, of the skeletal muscle pump in the legs aiding blood return to the heart.

In addition, there is evidence that a sudden fall in right atrial pressure can produce a paradoxical dramatic rise in skeletal muscle vasodilation and a sudden fall in peripheral vascular resistance inducing fainting, as first identified by Barcroft et al. (43) in research undertaken during the Second World War (1944).

Thus it may be that the ultimate cause of the postural hypotension experienced by athletes completing long distance running events is a sudden vasodilation resulting from a sudden fall in right atrial pressure which begins the moment the athlete stops exercising. If this is correct, it has important implications for the treatment of the common condition of post-exercise collapse in marathon runners (see below).

5. *There are no clinical trials to show that intravenous fluid therapy is either beneficial or even necessary for the optimum treatment of those athletes who collapse* ***after completing marathon races*** *and who seek medical care as a result.*

The assumption that athletes collapse after exercise because they are suffering from a dehydration-related heat illness has led to the widespread use of intravenous fluids as the first line of treatment for this condition of exercise-assocated collapse.

But if the condition is really due to a sustained vasodilatation perhaps in response to a dramatic reduction in right atrial pressure (43) that begins at the cessation of exercise, then the most appropriate treatment is to increase the right atrial pressure. The most effective method to achieve this to nurse the collapsed athlete in the head down position, according to the method depicted in Figure 1.

Since adopting this technique in the two races under our jurisdiction in Cape Town, South Africa, we have not used a single intravenous drip in the past 2 years in the management of the 56km Two Oceans Marathon (total number of finishers in the 2 years - 16XXX runners) and the 224 km Cape Town Ironman Triathlon (total number of finishers in the past 2 years - ~ 1000). We found no evidence that the management of these athletes was compromised in any way as a result of the adoption of this novel treatment method.

Since there are no clinical trials showing that intravenous fluid therapy is the optimum treatment for this condition and because there is no logical reason to believe that this form of treatment would provide any particular physiological benefit, it is my suggestion based on my own clinical experience, that the medical directors of marathon races should at least consider using the simple technique depicted in Figure 1 according to the guidelines we have developed (32, 33).

6. *The optimum rates of fluid ingestion during exercise depend on a number of individual and environmental factors. Hence it is neither correct not safe to provide a blanket recommendation for all athletes during exercise.*

The factors that determine the rate of sweat loss and hence the necessary rate of fluid ingestion during exercise are determined by a number of factors including the following:

- The rate of energy expenditure (metabolic rate) which is a function of the athlete's size and running speed;
- The environmental conditions particularly the humidity and the presence or absence of convective cooling (facing windspeed);

In general, it is found that the fastest running athletes lose between 1 – 1.5kg per hour during competitive marathon running. However, for reasons described earlier, this does not mean that this is the rate at which fluid must be replaced since a portion of that weight loss is from metabolic fuels that are oxidized and a part is from the release of water stored with muscle glycogen. Furthermore, there is no evidence that, during competition, elite athletes can drink at rates that come anywhere close to these rates of weight loss.

Rather all the evidence indicates that rates of fluid intake during running races vary from 400 – 800 ml per hour (1, 29). Only in those who develop the hyponatraemia of exercise are the rates of fluid ingestion during exercise very much higher and may reach rates of up to 1.5 liters per hour (7-9,44).

Accordingly one proposal is that runners should aim to drink between 300 – 800 ml per hour, with the higher rates for the faster, heavier runners competing in warm environmental conditions and the lower rates for the slower runners/walkers completing marathon races in cooler environmental conditions.

The first cardinal point is that athletes who run fast in the modern marathons that are more usually run in moderate environmental conditions appear to cope quite adequately despite what appear to be quite low levels of fluid intake during those races. Thus there does not appear to be any reason why elite athletes should be encouraged to increase their rates of fluid intake during marathon racing by drinking "as much as possible".

But perhaps the even more cardinal point is that athletes who run/walk marathon races in 5 or more hours will have low rates of fluid loss and must therefore be advised **not** to drink more than a maximum of 500 ml per hour during such races. They must be warned that higher rates of fluid intake can be fatal if sustained for 5 or more hours.

Finally a number of recent studies show that drinking "ad libitum" is as effective a drinking strategy during exercise as is drinking at the much higher rates proposed in the ACSM guidelines (45-47).

Accordingly perhaps the wisest advice that can be provided to athletes in marathon races is that they should drink "ad libitum" and should avoid drinking at rates that exceed about 800ml per hour.

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Figure 1. Proposed method for the initial evaluation and treatment of the postural hypotension that appears to be the cardinal physiological abnormality in athletes seeking treatment for post-exercise collapse following marathon and other long distance endurance events.

Table 1. Cases of exercise-related hyponatraemia reported in the literature: 1985-2001

70 Non-fatal cases with significant illness

Main presenting symptoms	Number (%)	Mean Serum $[Na^+]$	Range
Disorientation	34 (49)	125	117 - 131
Pulmonary oedema	13 (19)	121	115 - 127
Respiratory arrest	2 (3)	118	113 - 123
Seizure	22 (31)	117	108 - 124
Coma	6 (9)	113	107 - 117