Too much of a good thing?
The danger of water intoxication in endurance sports

INTRODUCTION

The deaths of four runners in the 2005 Great North Run alerted the public to the potential dangers of distance running. In the immediate aftermath, the Sports Minister recommended that runners be advised to 'drink more water'.[1] These comments would appear to be extremely sensible, and it is likely that most people seeking advice prior to participating in such an event would be encouraged to 'drink plenty of fluid'. It is therefore a seeming paradox that the medical director for the 2005 New York City marathon went to extraordinary lengths to advise participants to limit their fluid intake to no more than 750 ml per hour.[2] The dangers of water intoxication are well known among sports physicians, and are starting to become recognised by ultra-endurance athletes (competing in ultra-marathons or Ironman-distance triathlons), even if there is doubt in some lay minds about the cause. However, the message does not appear to be strong enough to re-educate a public that is given out-dated advice in magazines, and is bombarded with advertising from manufacturers of sports drinks, all stressing the importance of avoiding dehydration.

GPs are ideally placed to help educate participants in endurance events about the dangers of hyponatraemia of exercise. The London Marathon is the largest annual fundraising event in the UK. One-third of the available entries are allocated to charities and, as a result, each year a significant number of first-time runners seek medical clearance before they begin training. The slower novice or 'amateur–enthusiast' is at greater risk of developing hyponatraemia than the competitive athlete, and this is because they are prone to consuming too much fluid. Prevention of hyponatraemia rests on education about the dangers of excessive fluid intake. However, this is unlikely to be effective on its own without correcting the widely held belief that dehydration is the greatest danger faced by endurance athletes.

Endurance athletes are generally advised to consume enough fluids to prevent any degree of dehydration. This stems from the beliefs that dehydration is the greatest risk to health and performance during exercise, that the sensation of thirst is a late indicator of dehydration, and that all of the fluid lost during exercise must be replaced and can be done so without consequence. The scientific evidence does not support this position.

DISPELLING THE FEAR OF DEHYDRATION

Until the late 1960s, distance runners were actively discouraged from consuming fluids, partly for fear of gastrointestinal disturbance. Even so, it was possible to complete a full marathon (26.2 miles) in times that are still impressive.[3]

However, the focus of dehydration as the predominant problem faced by distance runners can be traced back to a 1969 paper entitled 'Danger of an inadequate water intake during marathon running',[4] even though marathon runners were not actually studied. The report showed that the fastest runners were the most dehydrated, but concentrated on the correlation between dehydration and core temperature, and not on performance. The erroneous conclusion that has persisted from this study is that fluid restriction leads to progressive dehydration, which in turn leads to heatstroke and potential collapse. However, this conclusion is completely at odds with the repeated observation that winners of marathons are among the most dehydrated and the most hyperthermic.[5] Over the course of a marathon and despite available fluids, elite runners will become voluntarily dehydrated, in part, because it is not possible to consume fluid in large volumes at competitive running intensity.[6] Dehydration by 5% is common in these runners, and voluntary dehydration during exercise has been observed elsewhere in those with free access to fluids.[7] Exercise is only terminated at much higher degrees of dehydration, and fluid resuscitation provides rapid recovery.

FLUID INTAKE DURING EXERCISE

Taken together, the above observations indicate that it is entirely possible to run a marathon at competitive intensity without consuming any fluids (or by consuming a limited volume), and that this will obviously result in a degree of dehydration. However, fluid consumption during prolonged exercise has been repeatedly shown to improve performance[8] beyond what can be achieved without fluids. Conversely, progressive dehydration leads to a multitude of physiological disturbances, including increased heart rate and core temperature, reduced cardiac output and stroke volume, and reduced blood flow to the skin and exercising muscles — all in proportion to the degree of dehydration.

The misinterpretation of the 1969 paper (as above) has led to the recommendation that athletes achieve 100% fluid replacement, the current position stand of the American College of Sports Medicine (ACSM).[9] Athletes are advised to drink the maximum amount that can be tolerated, or 600–1200 ml per hour.

In terms of performance, this recommendation does not stand up to experimental testing. Repeated studies have shown that, over prolonged (>2 hours) exercise, 100% fluid replacement does not improve performance compared to consumption *ad liberatum*.[8] At competitive racing intensity, 100% fluid replacement often leads to gastrointestinal distress.[6]

The second scientific criticism of this recommendation is based on the incorrect assumption that fluid losses account for all weight loss during prolonged exercise. The predominant fuels for endurance sports are glycogen (from muscle and

liver) and fat. Oxidation of these in the tricarboxylic acid (Krebbs') cycle leads to the production of 'metabolic' water. This is lost as sweat, but does not require replacing. Additionally, glycogen is stored in association with water, which is released when the glycogen is broken down. Again, this water is lost as sweat but does not require replacement. The total of this non-replacement water has been calculated as being up to 2 kg over a standard marathon,[10] and higher in longer events. This means that a runner who finishes a marathon at the same weight as at the start is overhydrated by as much as 2 litres.

The final criticism of this advice is that it assumes no danger from large volume fluid intake. This, too, is erroneous.

WATER INTOXICATION AND HYPONATRAEMIA OF EXERCISE

Hyponatraemia of exercise has generally been considered a rare event in endurance sports. However, the morbidity and mortality from this condition has been well reported in the medical literature.[3] While the mild form may be asymptomatic, severe hyponatraemia causes confusion, seizures and death. In contrast, there does not appear to be a single report of the death of an athlete in which dehydration was the clear cause.

A recent prospective study of runners in the Boston Marathon[11] revealed a 13% prevalence of hyponatraemia (serum sodium <135 mmol/L) and a 0.6% incidence of critical hyponatraemia (serum sodium <120 mmol/L) in race finishers. Equating this to the London Marathon: of a finishing field of 33 000, 4290 would have mild hyponatraemia and 198 would suffer from critical hyponatraemia. Obviously, this figure does not include those unable to complete the event. The Boston study also shed interesting light on the risk factors for this condition: slow (over 4 hours) race time, weight gain and body mass extremes, all of which confirmed the

Flora medica
Richard Lehman

From the journals, May–June 2006

***New Eng J Med* Vol 354**

1985 For some children with severe chronic asthma, corticosteroid inhalers should probably be used regularly; but for children with just a tendency to wheeze from time to time, this study showed no benefit from regular inhaled fluticasone.

1998 Giving inhaled budesonide early in episodes of wheezing in the first 3 years of life also has no effect.

2112 Do premature babies get a buzz when they are given caffeine? All we know is that it helps them breathe better.

2131 An 8-year study from England shows that children who have their hearing impairment picked up early by screening benefit in language skills, but not in speech.

2250 If you need to bone up on your knowledge of the various ways that bone can modify its structure, here's a well-illustrated and interesting review.

2340 'Even moderate weight gain among persons of normal weight may cause or exacerbate symptoms of reflux' in the Nurses' Health Study: GORD's punishment for indulgence.

***Lancet* Vol 367**

1618 A review of the difficult problem of pain that persists after the healing of surgical wounds: I wish that it offered solutions.

1665 Dual platelet inhibition with aspirin and dipyridamole is better than aspirin alone following TIA and minor stroke, though not by much. Have neurologists discovered clopidogrel yet?

1689 The decline of academic medicine in Europe is discussed with more bafflement than insight here. GPs of the world unite! You have nothing to lose but the chains of intellectual snobbery! You can do the research that matters.

1747 The *Lancet* treats us to another huge overview of the global burden of disease. Things are not all for the best in the best of all possible worlds, but they are getting better — except where the infrastructure of primary care has been destroyed.

1830 Should we criminalise all users of 'narcotics'? Or should we give them the means to obtain and inject them safely? Well, of course, if you want to open the floodgates … But Zurich demonstrates that the latter course actually decreases heroin use in the community.

***JAMA* Vol 295**

2275 Monoclonal antibodies to tumour necrosis factor α, such as infliximab and adalimumab, are effective in suppressing rheumatoid arthritis, but a meta-analysis of the trials shows that they double the risk of serious infection and malignancies over a fairly short period.

2357 Colonoscopy is the best way to screen for bowel cancer, and if you have a normal one, your chance of bowel cancer falls for at least 10 years. But if you are over 80, any mortality benefit is reduced by 85%.

***Arch Intern Med* Vol 166**

965 Oddly, giving up smoking and alcohol has no effect on oesophageal reflux: weight loss (see *NEJM* above) and raising the bed-head are the only non-pharmacological measures that work.

1003 Patients with heart failure have higher rates of Alzheimer's disease and other dementia.

1027 Unopposed oestrogen of various kinds slightly increased the risk of breast cancer in the observational Nurses' Health Study, unlike the Women's Health Study which found no increase in those randomised to equine oestrogens.

1092 The best way to tell if your patient is anxious is to ask: the GAD-7 scale is a quick way of doing it, as good as longer ways.

1115 To avoid dementia, keep physically active when you retire.

***Ann Intern Med* Vol 145**

715 The best way to tell if a woman has stress or urge incontinence is to ask. It's just as good as fancy scores and investigations.

785 Time for a coffee, or time for a nap? The two are just as good for long-distance night drivers. For hospital interns, napping helps clinical decision making (page 792). There's an editorial on page 856 musing on the perils of 'circadian dyschronosis'.

904 A meta-analysis of studies of long-acting inhaled β-agonists in asthma shows that they increase mortality, an effect not totally offset by concomitant inhaled steroids.

Syndrome of the Month: Twiddler's syndrome

'Twiddler's syndrome in a patient with an implantable cardioverter-defibrillator' (*Heart* 2006; **92:** 826). No, the eponym does not refer to some distinguished electro-cardiologist unfortunately named Twiddler. It refers to a patient who twiddled with the leads and damaged them, with shocking consequences.

Plant of the Month: *Stewartia pseudocamellia*

A beautiful small tree for lime-free soil, with delicate flowers for weeks when most other trees have given up.

prevailing theories arising from previous case studies. Of interest was the lack of any increased risk from drinking water compared to sports drinks.

Hyponatraemia of exercise is caused primarily by excessive fluid intake.[12] In ultra-endurance events such as ultra-marathons and Ironman triathlons, the situation becomes somewhat more complicated. Since the body's sodium levels determine water content, the continued loss of sodium in sweat can lead to a progressive loss of fluid reserves. In such ultra-endurance events, an adequate sodium intake is therefore necessary to correct dehydration without causing a dilutional hyponatraemia. Despite this, excessive fluid intake remains the predominant cause of hyponatraemia in all endurance events.

This aetiology explains the significance of weight gain as a risk factor in the Boston study. As explained above, competitive runners are unable to consume excessive volumes of fluid. However, high volume fluid consumption is relatively easy in slower runners, especially if they adopt a run-walk strategy and walk through the drinks stations. The problem is then made even more likely by the presence of drinks stations at almost every mile in most marathons. But because of their lower running intensity and lower sweat rates, these are the very runners who do not need to consume fluid in large volumes.

Sports drinks certainly lead to increased fluid absorption in the intestine (due to co-absorption of carbohydrate), and provide a source of carbohydrate that may help to prevent the phenomenon of 'hitting the wall'. Formulas containing sodium (almost all at lower concentration than found in sweat) do help to limit the fall in serum sodium, in part by allowing maintenance of urine output.[13] In theory, sports drinks should help to prevent hyponatraemia, although this is unproven.

CONCLUSION AND RECOMMENDATIONS

Hyponatraemia of exercise is a well-recognised condition and a recent report has indicated the incidence during a large city marathon race, although further studies are needed to confirm this. The condition results from excessive fluid intake during prolonged exercise, which stems from erroneous advice given to athletes that their goal should be 100% fluid replacement. This recommendation is based around the belief that any degree of dehydration is highly dangerous, despite fluids having been shunned by marathon runners for many years, and today's elite runners finishing with a variable degree of dehydration. A 100% fluid replacement strategy is neither necessary for performance nor physiological, since it actually results in over-hydration. Similarly, over-hydration prior to an event should be discouraged, since this also promotes hyponatraemia. However, the reasoned scientific debate on this topic over the last 10 years has had little effect on the public, predominantly due to the influence of advertising and non-medical coaching advice in popular running and triathlon magazines.

Re-education of endurance athletes about the dangers (and ease) of over-hydration is the most important means of preventing this condition. Slower athletes are particularly at risk. In a marathon, those runners who are likely to complete the race in over 4 hours, or those likely to utilise a run-walk strategy, are at a higher risk of hyponatraemia.

A high degree of responsibility also lies with the event organisers to ensure that runners are made aware of the dangers of hyponatraemia, and how to guard against it. The efforts of the New York Marathon medical director demonstrate that it is possible to alert all participants in a marathon to this problem. Entrants in Ironman-distance triathlons are already provided with warnings about the dangers of hyponatraemia, but advice to guard against excessive intake is not listed as the predominant cause. There are even warnings about hyponatraemia at the Grand Canyon National Park in Arizona, US. However, the website for the 2006 London Marathon contains no specific information about hyponatraemia or warnings concerning excessive fluid intake.[14]

Athletes need to be reassured that a mild degree of weight loss over an endurance event is acceptable, whereas no weight loss represents over-hydration. Drinking according to the perception of thirst appears safe. Specific advice on hourly volume intake is ill advised, but would typically be between 400 and 800 ml per hour. The faster, larger athlete racing in hot weather will have higher requirements, whereas those for the smaller slower runner taking part in cold conditions will be lower.

From personal experience of developing hyponatraemia during ultra-endurance sports, the first objective symptom is confusion (consistent with published reports[15]). However, the assumption must not be that an athlete in this condition is simply dehydrated. Confused marathon/Ironman triathlon finishers should always have their weight checked, and this compared to pre-race weight (which can and should be recorded on the race number at the pre-race registration formalities). While athletes who are dehydrated will respond rapidly to intravenous fluid administration, this same course of treatment would prove disastrous to an already fluid-overloaded individual.

Experts in this area of exercise medicine firmly believe that the case for 100% replacement has been satisfactorily thrown out.[16,17] Unfortunately, the world's largest organisation of sports physicians has yet to issue a formal change of its recommendations and so, in the face of advertising and erroneous magazine advice, the message is not reaching many athletes, novice or experienced. It is the unfortunate amateur–enthusiasts and novices who are most likely to suffer.

Angus H N Whitfield

Competing Interests

The author has stated that there are none.

Acknowledgments

The author wishes to express his gratitude to Mr Alex Billioux and Mr Hugh Whitfield for their assistance.

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Mike Fitzpatrick

James Parkinson: a man for our times

Defenders of Prince Charles' continuing campaign for the integration of complementary therapies within the NHS have criticised prominent specialists, who declared their opposition to this campaign, on the grounds that they did not include any GP or other representative of primary care.[1] These specialists have been condemned as 'old-fashioned' because they do not believe that patients' interests would be served by doctors retreating to modes of treatment, most of which were superseded by modern medical practice more than a century ago. It is bizarre that what is now considered progressive in medicine is a willingness to pursue the hobbyhorses of the heir to the throne and his endorsement of techniques such as homeopathy, the most efficient way yet discovered of turning water into money, as described memorably by Tony Copperfield in a recent Doctor column.

It is indeed sad to see no GP signatory to breast surgeon Michael Baum's letter challenging Prince Charles' truly reactionary campaign. It is also regrettable to note that there appears to be no prominent GP backing for the Oxford Pro-Test campaign in favour of experimentation on animals and against the attempts by animal rights activists to intimidate those involved in the construction of new research facilities. By contrast, it is noteworthy that one of the leading supporters of the campaign is neurosurgeon Tipu Aziz, a pioneer in research and treatment for Parkinson's disease.

James Parkinson, who described the eponymous disease in his celebrated 1817 work, *An Essay on the Shaking Palsy*, was of course a GP in Hoxton, in what is now the London Borough of Hackney, just down the road from my surgery.[2] Parkinson was a man of the Enlightenment, a radical who was a suspect in the 'Pop-Gun Plot' to kill George III (with a poison dart) in 1794, a geologist and fossil hunter as well as a physician and surgeon. He offers a model for our confused times.

Parkinson's description of the 'shaking palsy' is a masterpiece of clinical observation. Yet it begins and ends with an appeal 'to those who humanely employ anatomical examination in detecting the causes and nature of disease' to 'extend their researches to this malady'. He pays tribute to the anatomists: 'to such researches the healing art is already much indebted for the enlargement of its powers of lessening the evils of suffering humanity. Little is the public aware of the obligations it owes to those who, led by professional ardour and the dictates of duty, have devoted themselves to these pursuits, under circumstances most unpleasant and forbidding'.[2] What a contrast with contemporary discussions of human dissection, in which popular distaste is generally met by professional defensiveness.

A recent work of medical history, which offers a welcome challenge to the prevailing post-modernist relativism by embracing the concept of progress in medical science, nevertheless echoes current prejudices in disparaging the anatomists and physiologists of the past for 'mangling the dead, torturing the living'.[3] The author condemns Claude Bernard's pioneering 19th century experiments on animals — generally acknowledged as the foundation of modern physiology — as 'gruesome and grotesque'. Yet medical understanding — and medical treatment — of conditions such as Parkinson's disease have advanced over the past 200 years through both dissection and vivisection, often in the face of public hostility. Following the localisation of the 'proximate cause' of Parkinson's disease in dopamine depletion in the substantia nigra in the midbrain (Parkinson suspected the medulla oblongata in the brain stem), it has become possible to relieve some of the symptoms of the condition with the dopamine precursor L-dopa and with dopamine antagonists. In part, through experimenting on monkeys, Tipu Aziz and others have developed 'deep brain stimulation' through implanted electrodes, a technique from which 40 000 people have already benefited.

Instead of seeking royal patronage or pandering to fashionable prejudices (whether for alternative health treatments or against experimentation in any form), today's doctors would better follow the robust republican, democratic and scientific principles of James Parkinson, the Jacobin GP of Hoxton Square.

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