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THE TRUTH ABOUT SPORTS DRINKS

Sports drinks are increasingly regarded as an essential adjunct for anyone doing exercise, but the evidence for this view is lacking. **Deborah Cohen** investigates the marketing of the science of hydration

Prehydrate; drink ahead of thirst; train your gut to tolerate more fluid; your brain doesn't know you're thirsty—the public and athletes alike are bombarded with messages about what they should drink, and when, during exercise. But these drinking dogmas are relatively new. In the 1970s, marathon runners were discouraged from drinking fluids for fear that it would slow them down, says Professor Tim Noakes, Discovery health chair of exercise and sports science at Cape Town University. At the first New York marathon in 1970, there was little discussion about the role of hydration—it was thought to have little scientific value.

So how did the importance of hydration gain traction? An investigation by the *BMJ* has found that companies have sponsored scientists, who have developed a whole area of science dedicated to hydration. These same scientists advise influential sports medicine organisations, which have developed guidelines that have filtered down to everyday health advice. These guidelines have influenced the European Food Safety Authority, the EU agency that provides independent advice on the evidence underpinning health claims relating to food and drink. And they have spread fear about the dangers of dehydration.

Much of the focus on hydration can be traced back to the boom in road running, which began with the New York marathon. Manufacturers of sports shoes and the drink and nutritional supplement industries spotted a growing market.

One drink in particular was quick to capitalise on the burgeoning market. Robert Cade, a renal physician from the University of Florida, had produced a sports drink in the 1960s that contained water, sodium, sugar, and monopotassium phosphate with a dash of lemon.[1 2] Gatorade—named after the American Football team, the Gators, that it was developed to help—could prevent and cure dehydration, heat stroke, and muscle cramps, and improve performance, it was claimed.[2]

The first experimental batch of the sports drink cost $43 (£28; €35) to produce but has spawned an industry with sales of around £260m a year in the UK alone—and consumption is increasing steadily. "The buzz around sports and energy drinks is here to stay. This has remained the fastest growing sector in the UK soft drinks market," an industry report suggests.[3] In the US the market is even bigger. In 2009, forecasters, Mintel, valued it at $1.6bn, and the market is projected to reach $2bn by 2016.[4]

The rapid rise in consumption is hardly surprising—sports drinks have the might of multinationals behind them. PepsiCo bought Gatorade in 2001 and both Coca-Cola and GlaxoSmithKline (GSK) make sports drinks—Powerade and Lucozade respectively. The companies are a partner and service provider to the London 2012 Olympics.

The key behind the rise in consumption of sports drinks lies in the coupling of science with marketing. What started life as a mixture of simple kitchen foodstuffs has become an "essential piece of sporting equipment."[5]

According to Noakes, the sports drink industry needed to inculcate the idea that fluid intake was as critical for athletic performance as proper training. "It became common for athletes to state that the reason why they ran poorly during a race was not because they had trained either too little or too much, but because they had become dehydrated. This was a measure of the success of the industry in conditioning athletes to believe that what they drank during exercise was as important a determinant of their performance as their training," he says.

Indeed, after the "invincible" Australian cricket team lost the 2005 Ashes test series to rivals England, a research fellow at the Australian Institute of Sport (AIS) started to monitor players' levels of dehydration.[6]

The previous year (2004), the institute had entered a partnership with Gatorade. The AIS's first Gatorade fellow, Kelly Drew, conducted a study on hydration among the cricketers, taking urine samples and testing their sweat. "We do know that 50% of them turned up today dehydrated, which is not a good sign," she said.[6]

The AIS is just one organisation backed by Gatorade—other powerful sports medicine organisations also receive funding from drinks companies. The US National Athletic Trainers' Association (NATA), a representative body of sports health professionals with over 35 000 members, works closely with Gatorade.

The company has taken out advertisements in NATA's newssheet that look like academic papers. These "research adverts" are just one example of how companies promote the idea that the benefits of their drinks are based on decades of thorough scientific research.

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Selling science

Gatorade documents from 2010 show that sales staff are encouraged to watch an internal video called "Selling the Science" and told to "make sure consumers understand the science behind Gatorade." Promotion also hinges on the notion that sports drinks are among the "best researched food products on the planet," Bob Murray, a former director of the Gatorade Sports Science Institute wrote in 2001.[7]

And they're not the only ones—when GSK reshuffled its entire communications department earlier this year, it said a key part of its strategy would be promoting the science behind its products. "The science that goes into our brands is a competitive advantage. Lucozade, for example, is subject to more than 100 clinical trials," a spokesperson said.[8 9] The company has suggested that the "market is all about credibility."[10]

In recognition of this, GSK set up the Lucozade Sports Science Academy (LSSA) in 2003, comprising a sports nutrition website, links with leading universities, and a high-tech gym at the company's headquarters.[10] Marketers intended that bottles of the drink would be stamped with the LSSA insignia to reaffirm the scientific credibility when sports nutrition toolkits were handed out to gym instructors to educate them in the use of Lucozade Sport products.[10]

Indeed, just as drug companies have appointed key opinion leaders to influence doctors' prescribing patterns, sports drink and supplement companies seek to work with gyms and instructors. Virgin Active has a partnership with Powerade, for example,[11] and the GSK owned supplement brand, Maximuscle, has a partnership with LA Fitness.[12]

Like GSK, Gatorade has pushed heavily on the science. In 1985, Gatorade, then owned by Quaker Oats, set up its Gatorade Sports Science Institute (GSSI) in Barrington, Illinois, to conduct and publish research and to educate sports health professionals and athletes on sports nutrition and exercise science.

Just as drug companies held sponsored symposiums in exotic locations, Quaker Oats held invitation only annual conferences in locations around the world . Attendees included advisers to the world's most influential sports authorities.

Indeed, the editors of a sports medicine book on performance were among them. Ron Maughan, Louise Burke, and Edward Coyle, coeditors of *Food, Nutrition and Sports Performance II: The International Olympic Committee Consensus on Sports Nutrition*, published in 2004, all have financial links (personal or institutional) to Gatorade and their book was supported by Coca-Cola, the makers of Powerade.

Taking on thirst

Perhaps one of GSSI's greatest successes was to undermine the idea that the body has a perfectly good homeostatic mechanism for detecting and responding to dehydration—thirst. "The human thirst mechanism is an inaccurate short-term indicator of fluid needs . . . Unfortunately, there is no clear physiological signal that dehydration is occurring," Bob Murray from the Gatorade Sports Science Institute declared in 2008.[13] Others have followed suit. Powerade say: "Without realising, you may not be drinking enough to restore your fluid balance after working out."[14]

And the International Olympic Committee's nutrition advice for athletes —published in 2003 and updated in 2008 in conjunction with Powerade—doesn't mention thirst once, even though it includes advice on fluid intake. "Dehydration impairs performance in most events, and athletes should be well hydrated before exercise," it says in its booklet, *Athletes' Medical Information*.[15]

Athletes are bombarded with different advice and given complex algorithms to calculate their individual hydration needs. They are told, for example, to rehydrate with a pint for every pound in body weight lost—a drop of 2% is considered a cause for concern. They are also told how to calculate their sweat rate and to check the colour of their urine (box).[15 16]

This advice has filtered down to healthcare organisations giving advice to patients playing sport. Diabetes UK, for example, advises people: "Drink small amounts frequently, even if you are not thirsty— approximately 150 ml of fluid every 15 minutes—because dehydration dramatically affects performance."[20]

"The problem was industry wanted to sell more products so it had to say that thirst was not adequate"

Studies suggest that thirst is a more reliable trigger. A meta-analysis of data from cyclists in time trials concluded that relying on thirst to gauge the need for fluid replacement was the best strategy.[21] "The problem was industry wanted to sell more products so it had to say that thirst was not adequate," Noakes says. And he should know—Noakes developed a sports drink with South African company, Leppin, in the 1980s.

Link ups with industry

Academics were in the vanguard of the drive against thirst and the promotion of the dangers of dehydration. In 1993, a group of experts led by Ron Maughan, professor of sport and exercise nutrition at Loughborough University and a member of GSSI's sports medicine review board since 1990, produced a consensus statement at a meeting funded by Isostar, a sports drink then owned by drug company, Novartis. "There is a need to make athletes more aware of the dangers of dehydration and of the importance of adequate fluid intake. Water is not the best fluid for rehydration, either during or after exercise," they wrote in an article published in the *British Journal of Sports Medicine*.[22]

In America, the sports drinks industry also made a push into the area of clinical science. In 1992, the American College of Sports Medicine—the "premier organization in sports medicine and exercise science" with over 45 000 members—accepted a $250 000 donation from Gatorade.

Four years later, in 1996, the American College of Sports Medicine produced guidelines that adopted a "zero % dehydration" doctrine, advising athletes to "drink as much as tolerable."[23] This guidance grew out of a roundtable meeting in 1993 "supported" by Gatorade.[24]

Half the guideline's authors either worked with the US military—the world's biggest customer of Gatorade—or had a financial relationship with the Gatorade institute. Over time, these authors would strengthen their relationship with the college, with Lawrence Armstrong and Michael Sawka—who both work for the United States Army Research Institute of Environmental Medicine—becoming senior editors of the college's journal in the past 10 years.

The college's ex-president, W Larry Kenny, even wrote that they cautioned against physically active people "letting their thirst guide them."[25]

The 1996 guidance stood until 2007, when in updated guidance the college acknowledged that people should drink according to thirst. However, it still promoted the idea that people should lose no more than 2% of body weight during exercise, and this remains the position in the published literature—although how people are meant to know how much weight they are losing while exercising isn't made clear.[26]

Three of the six authors of the updated guidance declared major financial conflicts of interest.

Lucozade's transformation

PICTURE POST/HULTON ARCHIVE/GETTY

Although it is now associated with sport, Lucozade had a sickly start in life. Initially developed by a pharmacist in Newcastle, Glucozade—as it was then called—was launched as a glucose supplement to help people recover from common illnesses and was soon snapped up by Beecham (now part of GSK's Nutritional Healthcare division). But illness doesn't sell in quite the same way as strength and health. The Lucozade that is familiar today was effectively created in 1983 by UK branding agency Ogilvy & Mather. It was relaunched with British Olympic gold medal winner Daley Thompson under the proposition that energy and empowerment were a stronger sell than recovery.

Randy Eichner and Nina Stachenfeld had financial ties to Gatorade, and Ronald Maughan had received funding from Coca-Cola and GSK, as well as being on the GSSI review board. Louise Burke had no personal financial ties, although her institution, the AIS, received funding from Gatorade. The other two authors, Michael Sawka (chair of the committee) and Scott Montain, worked for the US military and had attended the exclusive Quaker Oats meetings in the 1990s. Even two of the five reviewers—Michael Bergeron and Mark Hargreaves—declared financial links to Gatorade.

There is nothing wrong with working with industry. Indeed, a UK parliamentary select committee heard in 2006 that "sports science tends to be a Cinderella subject, which does not have the drivers. A lot of the money does come from the drinks industry and so on but it cannot be entirely independent." Links with industry are also seen as a badge of honour.

However, Paul Laursen, adjunct professor at the Sports Performance Research Institute in New Zealand, thinks that people with conflicts of interest shouldn't be writing guidance.

"Those people would say that 'we've done all the research, so we know the subject'. You need people who are more objective than that—who can put the studies into context and account for important limitations to the research," he says.

The *BMJ* asked the college why it chose people with such conflicts of interest to produce its guidance. A spokesperson said: "ACSM follows best practices regarding corporate relationships, disclosures, and conflicts of interest," adding that the college has "demanding requirements in the areas of disclosure and avoidance of conflict of interest." The college also maintains that the "chairs of both the 1996 and 2007 Position Stands on fluid replacement were US federal government employees with no professional affiliations with the sports beverage industry."

Despite all the guidance about the dangers of dehydration during exercise, Arthur Siegel, associate professor of medicine at Harvard University and adviser to the Boston marathon, says that there is no evidence that anyone doing a marathon has ever died from it. "Dehydration has gotten all the press and attention partly because of sports medicine associations who have endorsed the dangers of dehydration, but in fact dehydration is not life threatening," Siegel says.

Fluid is freely available in the races should a runner need to drink—they are not stranded in the desert with no access to fluids, he says.

"It [dehydration] is a normal biological response to exercise. You lose water; you get thirsty; you drink. End of story," Noakes adds. He is, however, considered maverick in his views.

Hyponatraemia

Against this background of what Noakes says is disease mongering, a genuine illness associated with sport has become a real concern—that of exercise associated hyponatraemia. There have been 16 recorded deaths and 1600 people taken critically ill during competitive marathon running because of a drop in their serum sodium (see linked commentary).[27]

The cause of this is keenly debated—in particular whether it is the volume or type of fluid consumption that is most to blame. The largest prospective study, conducted in a diverse group of marathon runners (funded by the National Institutes of Health and published in the *New England Journal of Medicine*), found no association with the composition of fluids consumed and concluded that it is the volume of fluid that is the main factor leading to hyponatraemia.[28]

According to lead author Christopher Almond, assistant professor of paediatrics at Boston Children's Hospital: "The available evidence indicates that the most effective way to prevent hyponatremia during marathon running is to avoid a positive fluid balance."[28]

A literature review in a nephrology journal also backed this up saying there is no evidence that "consumption of sports drinks (electrolyte-containing hypotonic fluids) can prevent the development of exercise associated hyponatraemia."[29] However, companies are keen to imply that it is water that is the problem.

Coca-Cola, for example, acknowledges that hyponatraemia is a cause for concern "for anyone doing endurance sports," but says that this is due to the failure to "replace the sodium lost through sweat or drinking a very large volume of very low-sodium beverages such as water." The Powerade webpage describing hyponatraemia does not mention that it can also happen if sports drinks are consumed.[30] The company has subsequently said it has updated the advice on its website "to ensure that it is clear that athletes should not over consume any liquids."

But the message has filtered down. "To prevent hyponatremia and electrolyte imbalances, athletes should replace lost body fluid with drinks that contain electrolytes, such as sports drinks," MedicineNet website says.[31]

Outreach to schools

The industry push has not stopped with adults participating in sports. GSK has developed an educational outreach programme called Scientists in Sport (www.scientistsinsport.com) as part of its involvement in the Olympic anti-doping operations. The programme includes materials for "GSK Ambassadors to take into schools, and free classroom resources."

One lesson looks at osmosis and water: "During intense exercise, heavy sweating removes water and salts from the body. If large quantities of water alone are consumed, this will dilute the normal

SCAREMONGERING OVER THE EFFECTS OF DEHYDRATION

The ACSM guidelines also emphasised the relation between dehydration and serious illness in sport saying that it causes heat exhaustion, heat stroke, muscle cramps, and exacerbates rhabdomyolysis. As well as a few laboratory studies, the ACSM draws on findings that dehydration was present in 17% of hospital admissions for heat stroke in the US military and a similar number in Israel.[24] It did not conduct a systematic review on the area.

Sandy Fowkes-Godek, director of the HEAT Institute and a professor of sports medicine at West Chester University, has conducted dozens of studies on National Football League players and failed to show that dehydration has an effect on core temperature. "It's a scare tactic that has worked very well," she says, "We don't understand what causes exertional heat stroke."

Studies that have shown that dehydration causes heat illness, she argues, have been set up to show it. Paul Laursen agrees.

"What is done in a lab doesn't always turn out to be true in outdoor conditions. Studies in hydration are often conducted in a climate chamber without appropriate airflow. They typically don't use a good fan, so the ability to remove heat from the body is reduced, and core temperature rises. While this might be what happens in an indoor fitness class, it isn't applicable to what goes on outside. But companies have taken this lab finding and made it gospel," he says.

A review in the *BJSM* supports this. "There are very few recent well controlled exercise physiology studies of heat and exercise in children that are directly applicable to real world field conditions," it says.[49] Indeed, a spokesperson from Gatorade confirmed that there have been no systematic reviews that address the relation between exertional heat related illness and hydration.

From a health perspective, Fowkes-Godek worries that if people are going to be fooled into thinking that drinking fluids is going to stop them getting heatstroke, they won't take other preventive measures. This advice has been picked up widely. NHS Choices website says that dehydration in exercise "is the primary cause of heat exhaustion."[50]

Disease mongering is a well documented phenomenon in healthcare,[51] and Noakes suggests that industry has followed a similar pattern with dehydration and exercise.

"When industry wanted to sell more product it had to develop a new disease that would encourage people to overdrink," he said adding: "Here's a disease that you will get if you run. Here's a product that is going to save your life. That's exactly what they did. They said dehydration is a dreaded disease of exercise."

concentrations of sugars and ions in the blood and tissues. Water will enter, by osmosis, and stop the muscles, nerves and the brain from working properly. In extreme cases, water intoxication can occur and may lead to death," it says. Students are then asked which drinks are closest to being isotonic and whether sports drinks justify their prices.

GSK maintains that the programme does not mention its sports drink. However, it admits that the introduction to the osmosis lesson—as quoted above—could be "made more relevant to the subject." "We are therefore going to update this section," a spokesperson told the *BMJ*.

But efforts to encourage children to drink sports drinks do not end there. This year, Gatorade and the NATA united to declare 11 July the first annual National Recovery Day for high school athletes in the US. This was "to focus the attention of athletes on the importance of proper athletic recovery." Children were told to "drink 16-24 ounces of fluid with sodium for each pound of body weight lost during exercise following a workout or game."[32]

Many schools in the UK now encourage children to stop every 15-20 minutes during exercise to drink. Football teams also instruct children to bring a bottle—no football field is seen without a colourful array of sports drinks.

This practice may be one that originated with Gatorade. In 2000, a former professor of paediatrics at McMaster University in Canada, Oded Bar-Or, who was also a member of the GSSI medicine review board, promoted the need for children to stop during sporting activities in order to drink.

"One should make certain that children arrive fully hydrated for a practice session or for competition and enforce drink pauses every 15-20 min during prolonged activities, even when the child does not feel thirsty. If necessary, rules of the sport should be modified to facilitate periodic drinking," he wrote in 2000.[33] That same year he was the main consultant to the American Academy of Pediatrics guidance on heat illness and exercise.[34]

"Children frequently do not feel the need to drink enough to replenish fluid loss during prolonged exercise. This may lead to severe dehydration," it said, adding: "A major consequence of dehydration is an excessive increase in core body temperature."

Updated advice in 2011 had Michael Bergeron—who has financial ties to Gatorade— as the main consultant and one of the lead authors. "Appropriate fluid should be readily accessible and consumed at regular intervals before, during, and after all sports participation," it added giving specific details about sweat replacement and amounts to drink. All references to this were to studies either funded by Gatorade or included authors with financial ties.[35] The Institute of Medicine, however, says: "Thirst and consumption of beverages at meals are adequate to maintain hydration."[36]

A spokesperson for Gatorade also confirmed that there were no systematic reviews on hydration in children. Instead, it pointed to three position papers that consider the relation between exertional heat related illness and hydration. These were from the ACSM and NATA and cite "carbohydrate-electrolyte solutions as one of many potential preventative steps."

In the UK, Maughan took a similar view. He wrote in 2001: "Children are particularly likely to forget to drink unless reminded to do so," adding that "mild levels of dehydration and hyperthermia will reduce exercise capacity."[7]

"Children are particularly likely to forget to drink unless reminded to do so"

This advice was soon adopted by groups lobbying for increased attention to hydration in schools. In the UK, an expert group on hydration was launched in June 2005, supported by the British Soft Drinks Association, with the "goal of improving the nation's hydration." Maughan was a key adviser.[37]

"If children have no understanding of why they need to drink frequently, and little or no encouragement is given, their health, wellbeing and performance may be at risk," the group's report concludes. It also laments the "demonisation of vending machines" in schools.[37]

War on water

The promotion of hydration has created a battle ground for the fight between bottled water companies and the sports drinks industry. While they both agree about the need to drink plenty of fluids,[38] there is disagreement on what that fluid should be.

The Natural Hydration Council—which represents the bottled water industry—warns that one in four adults drink sports drinks at their desk, thereby consuming unnecessary calories.[39] It urges that people should be encouraged to drink water rather than sugary drinks.[39] Sports drinks companies, however, promote the notion that their products are a superior source of hydration.

In its guidelines to casual runners taking part in the Lucozade sponsored national UK event Parkrun—Lucozade say that "water alone isn't enough to maintain hydration."[40] Powerade's website also suggests "Water is not enough." "Water doesn't have the performance benefits of a sports drink," it says.[41]

However, this is permitted. Earlier this year, the UK's Advertising Standards Authority (ASA) rejected a complaint against Powerade for television advertisements featuring Olympic heptathlon medal hopeful, Jessica Ennis, that said, "Powerade ION4 hydrates better than water."[42]

How good is the evidence?

Companies claim that the sodium in sports drinks stimulates thirst, resulting in the consumption of a higher volume of fluid and better retention compared with drinking water. Their claims also hinge on the physiological observation that the carbohydrate content of sports drinks aids water absorption from the small intestine. Consumers are told that another benefit is the taste to encourage higher fluid intake.

The ASA's judgment in favour of Powerade was revealing. Despite over 38 years of research, there was no published meta-analysis of studies in this area.[42] But the reason for this lack of evidence is clear, says Noakes. "A commercial company would never do research that it was not certain of the answer before it did the study," he says.

Yet Coca-Cola, GSK, and PepsiCo maintain that the scientific evidence supports their case—and they're not the only ones. In 2006, the European Union adopted new regulation that aimed "to ensure that consumers are not misled

"P" CHARTS AND URINE TESTS

The science of dehydration has led to another widely held belief that is not based on robust evidence—that the colour of urine is a good guide to hydration levels.

Like athletes, British soldiers are told to check their urine. The Ministry of Defence signed a £1.5m three year deal with GSK in 2005 to supply soldiers with Lucozade. "It is only recently that we have started to examine the science behind what our soldiers drink," the defence secretary, John Reid, said at the time.

The drink's packaging includes a "P chart," a colour code allowing soldiers to check their hydration levels by studying the colour of their urine.[17]

The Mayo Clinic's online guidance to patients also suggests urine is a good guide of hydration. "Unfortunately, thirst isn't always a reliable gauge of the body's need for water, especially in children and older adults. A better indicator is the color of your urine: Clear or light-colored urine means you're well hydrated, whereas a dark yellow or amber color usually signals dehydration," it says.[18]

However, a review of the evidence by Oxford University's Centre of Evidence Based Medicine linked to this investigation has assessed the predictive value of urine colour as a diagnostic test.

"There is a lack evidence for the widely recommended practice of assessing hydration status by looking at the colour of urine," it suggests.[19]

"The limited evidence shows that only first morning urine colour can be reliably used to assess dehydration and rehydration," it adds.

JAVIER LARREA/GETTY

by unsubstantiated, exaggerated or untruthful claims about foodstuffs." The European Food Safety Authority (EFSA) was charged with assessing the evidence supporting health claims.

Two related to sports drinks have been upheld: that they hydrate better than water and that they help maintain performance in athletes doing endurance exercise. This judgment did not apply to the ordinary person going to the gym or children playing football for an hour a week, Albert Flynn, chair of EFSA's dietetic products, nutrition, and allergies panel, told the BBC.

Because EFSA has reviewed the literature, companies say the evidence supporting the performance benefits of sports drinks is "very strong." But an analysis of the studies submitted to EFSA accompanying the investigation does not uphold this view. It also finds a troubling circularity in the industry influenced evidence base—and this does not just apply to the funding of the studies. EFSA also says it relied on the American College of Sports Medicine's 2007 review on hydration.[43] The *BMJ* asked the college about its methodology. While not providing substantive comment on the past methods, it said it "now uses an independent expert consultant in meta-analysis process."

When the Institute of Medicine analysed the same dataset they concluded that "many of the questions raised about the requirements for and recommended intakes of these electrolytes and of water cannot be fully answered because of inadequacies in the present database."[44]

In their determination to show that a solution of salt and sugar can produce a beneficial effect, companies have funded hundreds of studies over the past 40 years. The *BMJ* asked several companies for lists of these studies (see box for overview of research). GSK was the only one willing to provide such a list, comprising references to the "100 clinical trials" that suggest its sports drinks have important benefits. Gatorade did not respond, and Coca-Cola sent a detailed response explaining how their drink works.[45] An accompanying analysis of the studies found that the quality of the evidence was so poor that it was impossible to draw firm conclusions about the effects of the sports drink (box).[9]

JOURNALS' LINKS TO INDUSTRY

While many journals have scientists on their editorial boards who have links with the manufacturers of sports drinks—including the BMJ Group's *BJSM*—some have such people in prominent editorial roles.

The one with the biggest reach is *Medicine and Science in Sports and Exercise*. It's owned by the American College of Sports Medicine, which has a longstanding financial relationship with Gatorade and now Powerade. Since 1999, there has been a steady increase in the number of Gatorade affiliated scientists who are editors or on the editorial board. Over the past 12 years, the editors in chief have been Kent Pandolf and Andrew Young—both of whom work for the US military, Gatorade's biggest customer, and they have been instrumental in the science of hydration. Pandolf has been a speaker at invitation only GSSI conferences. Another senior editor, Michael Sawka, was chair of the committee who drafted the ACSM's 1996 "zero% dehydration" guidance on fluids. This was based on a roundtable funded by Gatorade. Sawka has been, and continues to be, a speaker at Gatorade sponsored events since 1989. It is not clear if he receives funding directly.

Ron Maughan, is also a senior editor of the journal. He has a longstanding financial relationship with Gatorade, as well as with Coca-Cola and GSK. Maughan has played senior editorial roles on several other journals over the past 20 years including the *BJSM*, *Nutrition*, the *European Journal of Applied Physiology,* and the *Journal of Sports Sciences,* the official journal of the British Association of Sports and Exercise Science, which has a financial relationship with Gatorade.[52]

Maughan is also coeditor of the *International Journal of Sport Nutrition and Exercise Metabolism* with Louise Burke who works at the Australian Institute of Sport, which has a partnership with Gatorade. This journal also has several Gatorade scientists on its editorial board.

Several other prominent Gatorade scientists sit on the board of the *Journal of Sports Science*. Mark Hargreaves, professor of exercise physiology and metabolism at Melbourne University and a member of the Science Advisory Board of the GSSI, is a consulting editor for the *Journal of Applied Physiology*—along with Sawka. This journal is owned by the American Physiological Society, which has financial links to Gatorade.

Another prominent editor of *Medicine and Science in Sports and Exercise* was Oded Bar-Or, a professor of paediatrics who had a longstanding financial relationship with GSSI. He has been a key consultant to the American Academy of Pediatrics on its hydration strategy.

Most of the scientists identified as being on the GSSI board have prominent roles in journals. Even its global senior director, Asker Jeukendrup, professor of exercise metabolism at Birmingham University, is an editor of the *European Journal of Sport Science*—the official journal of the European College of Sport Science. His biography states that "he has been a member of the advisory editorial board of the *Journal of Sports Sciences*, and served on the editorial board of the *International Journal of Sports Medicine* and *Medicine and Science in Sports and Exercise*. To date, Asker has served as a reviewer for 35 different scientific journals."[53] He is one of the main authors of research papers GSK gave the *BMJ* to demonstrate the effectiveness of its sports drinks.[9]

LYNNE CAMERON/PA ARCHIVE/PA IMAGES

Marketing to athletes or ordinary people?

Noakes has other concerns about the evidence. He questions how generalisable the results are to the public. The studies feature highly trained volunteers who sustain exercise at high intensity for long periods. "They are never going to study a person who trains for two hours per week, who walks most of the marathon—which form the majority of users of sports drinks."

Yet it's precisely these people that companies are targeting. Kelly Brownell, director of the Rudd Center for Food Policy and Obesity at Yale University has studied the way sports drinks are marketed. "They are marketed through a general route rather than just in runners' magazines, which shows they actually want a broad audience," he says.

Not all companies shy away from this description of their activities. John Brewer, director of the Lucozade Sport Science Academy, told a parliamentary select committee in 2006 that "It is really looking to get elite endorsement for high quality products that would then be preferred by the consumer at the mass market level."

But GSK's response suggests it would prefer not to be viewed in this light. A spokesperson told the *BMJ*: "Lucozade Sport is for adults who train and take part in sport and other vigorous physical exercise and this is stated on the bottle." The company also says that Lucozade is not marketed to children under 16. However, last year GSK turned to pop stars Tinie Tempah and Blink 182 drummer, Travis Parker—both popular with younger children— to become "brand ambassadors" and attract "sporty teenagers."[46]

Influence over journals

Another problem with the research is transparency. Even though a large proportion of the studies have been conducted by scientists with financial ties to Gatorade (PepsiCo), GSK, and Coca-Cola, the authors' individual conflicts of interest are either not published or not declared. Conflicts of interest also exist within the key journals in sports medicine—GSSI funded scientists pepper their editorial boards and editorships.

Around half of the studies supplied by GSK appeared in four journals—the *Journal of Applied Physiology* (20), *Medicine and Science in Sports and Exercise* (24), *International Journal of Sport Nutrition and Exercise Metabolism* (11), and the *Journal of Sports Science* (9). Several of these journals belong to organisations that have long relationships with Gatorade (box).

These links between sports medicine journals and the sports drinks industry may help to explain a characteristic of the sports drinks literature that is familiar to those who have analysed drug trials over the past 30 years—the relative (or almost complete) absence of negative studies.

FOOD ALAN KING/ALAMY

WHAT THE RESEARCH FOUND

The *BMJ*'s asked manufacturers to supply details of the studies underpinning sports claims. Only one manufacturer, GSK, provided a comprehensive list of the trials used to underpin its product claims for Lucozade—a carbohydrate-containing sports drink.[45] Other manufacturers of leading sports drinks did not and in the absence of systematic reviews we surmise that the methodological issues raised apply to all other sports drinks. **Carl Heneghan, Rafael Perera, David Nunan, Kamal Mahtani, and Peter Gill** set out to appraise the evidence and found a series of problems with the studies (see online for full article).[9]

Small sample sizes limit the applicability of results—Only one of the 106 studies —in 257 marathon runners—exceeded the acceptable target for a small study of 100 participants per group. The next largest had 52 participants and the median sample size was nine. Thus the results cannot be generalised beyond people with the study group characteristics

Poor quality surrogate outcomes undermine the validity—Many studies used time to exhaustion or other outcomes that are not directly relevant to performance in real life events

Poorly designed research offers little to instil confidence in product claims—Most studies (76%) were low in quality because of a lack of allocation concealment and blinding, and often the findings contrasted with each other. The studies often had substantial problems because of use of different protocols, temperatures, work intensities, and outcomes

Data dredging leads to spurious statistical results—Studies often failed to define outcome measures before the study, leaving open the possibility of numerous analyses and increasing the risk of finding a positive result by chance.

Biological outcomes do not necessarily correlate with improved performance—Reductions in use of muscle glycogen, for example, did not correlate with improved athletic performance. Physiological outcomes such as maximal oxygen consumption have also been shown to be poor predictors of performance, even among elite athletes

Inappropriate use of relative measures inflates the outcome and can easily mislead—One study inflated the relative effect of carbohydrate drinks from 3% to 33% by excluding from the analysis the 75 minutes of exercise both groups undertook before an exhaustion test

Studies that lack blinding are likely to be false—Studies that used plain water as the control found positive effects whereas those that used taste matched placebos didn't

Manipulation of nutrition in the run-in phase significantly affects subsequent outcomes—Many studies seemingly starve participants the night before and on the morning of the research study

Changes in environmental factors lead to wide variation in outcomes—Although dilute carbohydrate drinks may have some benefit in heat, studies found no effect in cold environments. No plausible reason given for benefits

There was no substantial evidence to suggest that liquid is any better than solid carbohydrate intake and there were no studies in children. Given the high sugar content and the propensity to dental erosions children should be discouraged from using sports drinks. Through our analysis, we have come to one conclusion: people should develop their own strategies for carbohydrate intake largely by trial and error.

Several people have told the *BMJ* how difficult it is to publish studies that question the role of hydration. Paul Laursen is one of them. "[A negative study] gets rejected by reviewers and the editors for really spurious reasons—particularly when you consider what does get published. It's a frustrating experience and it makes you wonder if it's a case of money winning out."

In response to concerns that drug companies were burying negative studies or those that demonstrated harm, the US government implemented the FDA Amendment Act. This stipulated that prospective studies had to be registered on a publicly accessible database. However, this has not caught on in nutrition.

When the *BMJ* asked companies if they had any knowledge of negative trials—where sports drinks have not shown improvement in outcomes—Coca-Cola responded that it didn't. "We would suggest you direct this question to an active researcher in the field," they said. But finding out what studies are being conducted isn't easy.

The *BMJ* turned to Loughborough University, which will form one of the UK's main hubs directing research into sport and exercise as part of delivering the Olympic legacy. The university receives funding from Gatorade. Using the Freedom of Information (FOI) Act, the *BMJ* asked for the university's contract with Gatorade and for the protocols of studies conducted on humans. The request was turned down under a commercial interests exemption. A subsequent letter said they didn't have any studies under way, yet declined to say what they receive funding for.

"The public interest in maintaining the exemption outweighs the public interest in disclosing the information," the FOI officer said.

UK Sport, a quango accountable to the UK's Department for Culture, Media and Sport, has also entered into a "research and development partnership" with GSK. This is "to investigate the role that nutrition has in improving athletic performance through the training process." They too turned down the FOI requests for study protocols, calling them "commercial in confidence."

Links to obesity

As sports drinks rise in popularity among children, there is concern their consumption is contributing to obesity levels. A 500 mL bottle of Powerade Ion4 contains 19.6 g of sugar, and the same sized bottles of Lucozade Sport and Gatorade Perform contain 17.5 g (32 g carbohydrates) and 30 g respectively (a teaspoon of sugar weighs about 4 g).

A report in June 2012 by the US philanthropic organisation, the Robert Wood Johnson Foundation, says that "the increased consumption of sports drinks in recent years is of growing concern for parents, health professionals, and public health advocates."[47]

Coca-Cola denies that the drinks are a problem. "No one single food or drink alone is responsible for people being overweight or obese. All foods and soft drinks can have a place in a sensible, balanced diet, as long as over time you do not take in more calories than you burn," it said.

However, endorsement by athletes and claims of hydration benefits have meant that sports drinks have shrugged off any unhealthy associations. An analysis by Yale University found that over a quarter of American parents believe that sports drinks are healthy for children.[48]

A recent campaign against the UK government levying value added tax on "sports nutrition drinks" by UK Sports Specialist Nutrition Alliance also shows how sport products are now thought of as essential. "You complain about obesity then charge us to live a healthy lifestyle!" says one signatory. "Why penalise individuals for choosing to use products designed to maintain health and vitality which ultimately help reduce the burden on the already stretched and under resourced NHS. We're sitting on a diabetes and obesity time bomb," says another.

This is why New York City's mayor, Michael Bloomberg, has proposed a ban on supersized bottles of soft drinks, including sports drinks. As one marketing pundit put it, drinking a sports drink "may be a way for consumers to convince themselves that they are looking after the bodies without having to break out into a sweat."[39]

Far from sports drinks turning casual runners into Olympic athletes, Noakes suggests: "If they avoided the sports drink they would get thinner and run faster."

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Related articles

- Mythbusting sports and exercise products by Carl Heneghan, Dan Lasserson, Jeremy Howick, Peter Gill, Braden O'Neill, Miriam Thacke and Matthew Thompson (*BMJ* 2012;345:e4848)
- The evidence underpinning sports performance products (*BMJ* Open 2012;2:e001702)

Food regulators must up their game

Matthew Thompson, **Carl Heneghan**, and **Deborah Cohen** find worrying deficiencies in the evidence used to support the health claims made for sports drinks

In 2006, the European Union adopted legislation to assess health and nutrition claims related to foods.[1] This aims to ensure that "claims made on food labelling and advertising regarding nutrition and health are meaningful and accurate, and can thereby help consumers in making healthy diet choices." From the end of 2012, all claims used to market and advertise a product will need to be approved.

The body responsible for evaluating the scientific basis of health claims is the European Food Safety Authority (EFSA). Their remit includes health claims related to the "roles of nutrients or substances in growth, development or functions of the body, psychological or behavioural functions, or slimming or weight control."[2]

After the legislation was passed, individual member states supplied the European Commission with a list of over 44 000 health claims. After duplicate or overlapping claims were removed, these were narrowed down to a final list of 4637 claims; EFSA has evaluated 2758 of them and has published scientific opinions on 341.[1]

EFSA uses five panels to evaluate the claims, one of which is the panel on dietetic products, nutrition, and allergies (NDA).[3] Scientific evaluations "should be scientifically substantiated" by "taking into account the totality of the available scientific data, and by weighing the evidence," in addition to reviewing the quality of the evidence. Evaluations are expected to show:

- The claimed effect of the food is beneficial for human health
- A cause and effect relation between consumption of the food and claimed effect (such as strength, consistency, specificity, dose-response, and biological plausibility)
- The quantity of the food and pattern of consumption required to produce the effect
- The populations in which the evidence was obtained are representative of the target population for which the claim is intended.[2]

Using this process, the NDA panel assessed scientific evidence related to three claims for carbohydrate-electrolyte solutions (sports drinks). They published their scientific opinion in June 2011 (table 1).[4]

How valid are EFSA's methods?

Given the importance of these claims for marketing of sports drinks in Europe (for both consumers and manufacturers) and the potential effect on health, we set out to assess the scientific evidence and the scientific rigour of EFSA's methods. We found a major discrepancy between what they set out to do, and what they actually did.

Methods to assess the effectiveness of interventions (or more correctly, methods that assess the balance between beneficial and harmful effects) have been established for several decades.[5 6] These methods of systematic review (or comparative effectiveness) are used by regulatory and professional organisations, guideline groups, and government bodies worldwide to assess drugs and medical devices or interventions such as diet, exercise, and counselling. However, the methods used by EFSA to assess the "nature and quality of the totality of the evidence," do not measure up to these transparent and reproducible methods (table 2).

Firstly, EFSA asked manufacturers of sports drinks to supply evidence for effectiveness of their own products. This presents a risk that manufacturers will selectively present studies that report products in a positive light. A better way would have been to ask for systematic reviews that detailed their search and appraisal methods, including studies with negative outcomes and unpublished studies. In the absence of systematic review evidence, a more comprehensive search for primary studies should be used.

Secondly, EFSA did not seem to have any criteria to decide what types of scientific evidence to accept, particularly in relation to study type or quality. Submissions included not only scientific studies, but also book chapters, opinion articles, and non-systematic review articles.

Thirdly, even for the scientific studies EFSA received, we were unable to track down the methods they used to assess quality. This could mean, for example, low quality studies were given the same "weight" as higher quality studies, potentially biasing results. Finally, when assessing a body of evidence it is important to present the data extracted from each of the studies, so that the methods of analysis (including meta-analysis where appropriate) are transparent and can potentially be reproduced by others. Although EFSA did helpfully publish a list of all the references it used to make its assessment,[4] it did not specify the process for analysing the evidence, suggesting that it used an ad hoc process.

Finally, EFSA states that its approach was an attempt to prove a "cause and effect relationship between consumption of the food and claimed effect." This seems an odd way of assessing the balance of beneficial and harmful effects of an intervention (in this case sports drinks).

We asked EFSA to confirm whether this was really its process and received this reply: "It's very straight forward in fact: an applicant has to submit all the research and data they think will prove that their claim is true. EFSA then reviews whatever has been submitted to support the validity of that claim, if EFSA finds that the research and scientific data submitted prove that there is a cause and effect relation between the product and the claim the evaluation is positive, if not, negative."

Our assessment of the evidence

We identified all references the EFSA panel cited for the two claims approved for sports drinks.[4] One author (MT) then examined the titles and, where appropriate, abstracts of all the references to identify scientific trials. For the scientific trials MT and CH then independently examined full text articles and extracted data on study type, study quality (using randomisation, allocation concealment, intention to treat, and blinding) to categorise studies as high, moderate, or low quality. We then assessed the relevance of each article to the claim for which it is cited and whether the outcome reported included a direct effect on sporting performance (such as time to complete a race or time trial). We also extracted details of study participants and calculated summary statistics for age, sex, and type of athlete.

Maintenance of endurance

EFSA listed 54 references related to the claim of maintaining endurance performance, of which only 26 were scientific studies (table 3 online). We were able to obtain full text papers for 25 of the studies and the abstract for the other. The studies included a total of 359 participants. Most (19/26) were poor quality. Participants were predominantly men (89%), endurance trained (73%), and aged 20-30 years (65%). Of the 26 studies, only 12 used an outcome that was related to improved sporting performance (running capacity, sprinting performance, tennis playing performance, etc), of which only one measured performance in a race setting—a randomised controlled trial of 98 marathon runners (which found no significant effect of sports drink compared with water on marathon time).

Table 1 | Claimed effects of sports drinks and EFSA panel conclusions about scientific evidence[4]

Claimed effect	Target population	Panel conclusions
Reduction in perceived exertion or effort during exercise (eg, delayed fatigue, increased endurance performance)	Active people who are exercising	A cause and effect relation has not been established
Enhancement of water absorption during exercise (eg, better or/faster fluid delivery, rehydration, hydration, electrolyte balance/rehydration)	Active people doing endurance exercise	A cause and effect relation has been established between the consumption of carbohydrate-electrolyte solutions and enhancement of water absorption during exercise
Maintenance of endurance performance (eg, increased endurance capacity, endurance in heat)	Active people doing endurance exercise	A cause and effect relation has been established between the consumption of carbohydrate-electrolyte solutions and maintenance of endurance performance

Table 2 | Comparison between accepted methods for assessing a body of evidence compared with what EFSA panel did to assess sports drinks

Accepted steps	What EFSA panel did	Potential effects on internal and external validity
Comprehensive and structured search of multiple electronic databases (or trial registries) for published (and unpublished) scientific studies	Relied on manufacturers to supply evidence for effectiveness	Serious risk of selection bias for positive studies or reports
Defined inclusion and exclusion criteria for deciding which types of studies are eligible	Apparently no defined inclusion and exclusion criteria, particularly in relation to study type, study quality, or outcomes of interest	Included not only scientific studies, but also book chapters, opinion articles, and non-systematic reviews
Assess the quality of included studies	Did not assess quality	Cannot take quality into account when interpreting findings
Summarise or analyse the included studies, using meta-analysis where appropriate	Published a list of all the references they used to make assessment	The process for analysing the body of evidence identified is not specified and suggests that an ad hoc process or consensus process was used

Enhanced water absorption during exercise

EFSA listed 108 studies related to water absorption during exercise, of which only 22 were scientific studies, most of which (17/22) were poor quality (table 3 online). The studies included a total of 298 participants, of whom three quarters (74%) were men; two thirds (67%) of the studies included people in their 20s (only three included people older than 30 years). Most studies were carried out on either general populations (eight) or regular athletes (seven) rather than endurance athletes or professionals.

Of the 22 studies, most (21) had outcomes that seemed to be relevant to the claim of water absorption during exercise, but only 16 used an outcome that was directly related to improvement in sporting performance or recovery (such as rehydration rates, running capacity, sprinting performance), none of which had an outcome that included performance in a race or event.

Limitations of the evidence

Putting aside our methodological concerns with EFSA's process to assess the scientific validity of the claims related to sports drinks, the body of evidence it cites in permitting the two claims seems to have serious limitations.

Firstly, the trials cited are small (median 9-10 people), including a total of only a few hundred people—and not all of them used an outcome directly related to the claim. Only one study measured outcome in a race. We were not able to determine whether the studies were biased to positive outcomes, but very few of the studies had equivocal or negative outcomes. Given that the scientific evidence submitted by just one manufacturer (GSK) exceeds that cited by EFSA,[7] we suspect the studies used by EFSA form only part of the available data on these products.

Secondly, many of the studies had methodological limitations, such as lack of blinding and concealment of allocation, use of laboratory rather than performance measures, and unrealistic study protocols.[7] EFSA's assessment did not comment on the availability and quality of the data. We did not attempt to summarise or meta-analyse the outcomes of the studies cited by EFSA because it would have been impossible to draw conclusions given the lack of detail on the methods it used to identify the included studies.

A third major concern is "representativeness to the target population," another criterion used by EFSA. For the claim that sports drinks improve endurance performance, the majority of participants in cited studies were young endurance athletes, and any evidence of benefit is therefore only applicable to such people. EU countries should therefore ensure that use of this claim in labelling or marketing of products makes it clear that the effect is limited to those participating in prolonged endurance exercise. The studies used to support the claim that sports drinks enhance water absorption included a wider spectrum of physically active people. Again most were men in their 20s, so it is difficult to know whether the findings (and the claims) apply to women, children, or older people, or only to those performing endurance exercise, which is the population for whom EFSA approved this claim.

Although many of the references cited by EFSA were review articles, none of them fitted the criteria for systematic reviews—most were consensus statements or clinical reviews. Moreover, EFSA did not seem to have a robust process to assess the validity of systematic reviews. For example, one of the prominent reports EFSA cites in support of these claims is a 1991 report of the Scientific Committee on Food.[8] The section of this document that reviews sports drinks (page 21), refers to five references, two of which seem to be non-systematic reviews, two are books or book chapters, and one a trial of eight men.

What should EFSA do now?

It will be up to individual countries to decide how to implement the claims permitted by EFSA. However, claims approved by EFSA will carry considerable weight and be valuable to manufacturers. There is a risk that claims approved by EFSA will be used to market sports drinks to people for whom the evidence does not apply. Moreover, public organisations that monitor advertisements for accuracy, such as the Advertising Standards Authority in the UK, will simply defer to published EFSA opinions when fielding complaints about adverts, rather than looking at scientific evidence themselves. There should be a process in place to challenge EFSA's decisions on claims (both those upheld and those rejected).

The timeline (and presumably resources) that EFSA was given to examine the scientific evidence for the thousands of food claims submitted to them was clearly insufficient, placing it under enormous pressure. Our observation of EFSA's processes suggests that it needs to develop greater expertise in the methods of systematic review—indeed, it has recently funded such in-house training. Improvements in skill and providing more time to assess new and appealed claims will facilitate a more scientific and rigorous approach to assessing the scientific basis of food claims in Europe.

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COMMENTARY

The role of hydration in health and exercise

Water is the major constituent of the human body and the total body water content is tightly regulated. The goal is to ensure that the water content of the cells and hence their size remains within a homeostatically regulated range.

Humans evolved as long distance persistence hunters on the arid savannahs of south and east Africa. We inherited the capacity to regulate our body temperatures during prolonged exercise in dry heat despite quite large reductions in total body water—no other mammal has the equivalent capacity.

Humans do not regulate fluid balance on a moment to moment basis. Because of our evolutionary history, we are delayed drinkers and correct the fluid deficits generated by exercise at, for example, the next meal, when the electrolyte (principally sodium but also potassium) deficits are also corrected.[1] As a result, there is no need to completely replace any fluid deficit as it develops either at rest or during exercise. Instead people optimise their hydration status by drinking according to the dictates of thirst.

Over the past 40 years humans have been misled—mainly by the marketing departments of companies selling sports drinks—to believe that they need to drink to stay "ahead of thirst" to be optimally hydrated. In fact, relatively small increases in total body water can be fatal. A 2% increase in total body water produces generalised oedema that can impair athletic and mental performance; greater levels of overhydration result in hyponatraemic encephalopathy— severe cerebral oedema that produces confusion, seizures, coma, and ultimately death from respiratory arrest.[1]

Why we feel thirsty during exercise

Sweat is a relatively dilute plasma secretion containing more water than electrolytes. As a result sweating increases blood sodium concentrations and osmolality. These increases are sensed by receptors in the hypothalamus, which respond by producing hormonal and behavioural changes designed to maintain the osmolality within the homeostatically regulated range.

Hormonal changes increase renal sodium and water conservation; reflex stimulation of the anterior cingulate gyrus produces the conscious sensation of thirst that drives water seeking behaviour. As the sensation of thirst rises, exercise performance becomes progressively impaired—a useful control since it reduces the exercise intensity and hence the possibility of continuing large water loss through sweating.

The sensation of thirst ceases when sufficient fluid and solute (electrolyte) have been ingested to correct the blood osmolality. This control ensures that humans always drink just enough but not too much. There is no intrinsic biological drive that will cause overdrinking. Voluntary overdrinking causes blood osmolality to fall, which should inhibit thirst and reduce the pituitary release of antidiuretic hormone (ADH). ADH regulates water reabsorption in the distal renal tubules and is one of the most potent human hormones. Paradoxically, athletes who develop exercise associated hyponatraemic encephalopathy report persistent thirst and retain fluid, even though their blood osmolality is falling; this suggests the presence of the syndrome of inappropriate ADH secretion.[1 2]

GALLO IMAGES/FOTO24/LOANNA HOFFMAN/GETTY

Timothy Noakes: dehydration's only symptom is thirst—the effect of which is to induce drinking

Dehydration in a sports setting

Dehydration is not a medical illness.[1] Correctly used, the term refers to a reduction in total body water content. Thus dehydration's only symptom is thirst—the effect of which is to induce drinking.[3] There is barely any risk that dehydration can occur in healthy athletes competing in a modern endurance event in which ample fluid is available.[1] Only when the total body water is reduced by about 15%—as occurs in those lost in the desert without water for more than 48 hours—is voluntary motor activity completely inhibited, resulting in paralysis.[1]

Confusion arose when the erroneous belief that all athletes who collapse after exercise are suffering from a dehydration induced heat illness was promoted as part of the false "science of hydration."[1] This dictated that people collapsing needed to drink more fluids during exercise and immediate resuscitation with large volumes of intravenous fluids.

However, athletes who collapse are neither hotter nor more dehydrated than control runners who complete the same races without collapsing.[1 4] Sporadic cases of heatstroke are also not caused by dehydration.[1 5] Hydration influences regulation of body temperature in competitive athletes only indirectly. The key determinant of the body temperature during exercise is the exercise intensity or metabolic rate; the greater the intensity, the higher the temperature.[1]

Humans can raise their body temperatures slightly more (adaptive heterothermy) when forced to exercise without any or optimum fluid replacement. The higher body temperature increases the gradient for heat loss by convection, thus reducing the need to increase sweat losses to maintain safe body temperatures and conserving water.

Treatment of collapsed athletes

Clinicians often assume that athletes collapse after exercise because they are hypotensive (and hyperthermic) as a result of dehydration. In fact, most have exercise associated postural hypotension, a form of vaso-vagal fainting that occurs in susceptible individuals within seconds or minutes after exercise terminates.[1 4 6] The treatment is recovery in the head down Trendelenberg position.[7]

Clinical signs of dehydration are unreliable in detecting substantial fluid loss in athletes completing endurance events.[8] Athletes who finish exercise with thirst are mildly dehydrated and need to eat and drink in order to replace their solute and fluid deficits.[1] Athletes who complete exercise without thirst do not need any specific treatment. Any presenting complaints in athletes who do not report that they are also thirsty cannot be caused by dehydration.

By contrast, the symptoms and signs of overhydration are unmistakable. The athlete shows marked changes in cerebral function, from mild withdrawal, to confusion, seizures, and coma. The diagnosis is confirmed by measuring blood sodium concentration; the lower the value, the more severe the fluid overload.[2 9]

Overhydration is treated by absolute fluid restriction and bolus 3-5% hypertonic saline infusions for those with confusion or coma.[10] This rapidly reverses the mental confusion in people with mild hyponatraemia[11] and produces rapid diuresis in those with exercise associated hyponatraemic encephalopathy. If brain swelling is so advanced that there is a high risk of respiratory arrest or cerebellar coning, diuretics and intravenous mannitol infusions may be needed.[12]

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