BMJ

BMJ 2012;345:e4848 doi: 10.1136/bmj.e4848 (Published 18 July 2012)

FEATURE

Mythbusting sports and exercise products

Carl Heneghan and colleagues examine the evidence behind the claims made for sports and exercise products

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There is no doubt that sport and exercise are beneficial for health and wellbeing. Yet, one might be fooled into thinking it is more important to heed correct nutrition and hydration advice than to actually exercise. In our analysis of the evidence of sports products[1] there were six claims that were so pertinent in terms of performance that we wanted to answer them with evidence. To find the evidence we searched PubMed Clinical Queries using systematic reviews and randomised controlled trial filters.

In terms of hydration we wanted to know if the colour of urine accurately reflects hydration and whether you should hydrate before exercise or just when you feel thirsty? For nutrition, we wanted to know whether carbohydrate-protein combinations and branched chain amino acids improve performance or recovery after exercise. Finally, we wanted to determine the benefits of caffeine ingestion and analyse whether wearing compression garments helps improve overall performance?

The colour of urine accurately reflects hydration

The qualitative measure of urine colour is viewed as a simple way to assess hydration status. Athletes are advised to "observe urine output over the course of a day and notice changes in urine flow and colour. Output volume and frequency should be consistent and the colour should be getting lighter towards the end of the day, aiming for the last outputs of the day being close to clear."[2] But recommendations from the American College of Sports Medicine state that urine colour is often subjective and might be confounded.[3] Many companies also provide a "urine colour chart" allowing athletes to quantify their level of hydration.[4 5]

Science behind the claim

Antidiuretic hormone is secreted by the posterior pituitary gland as a result of dehydration, resulting in increased water absorption in the collecting ducts of the kidneys. This decreases urine output and concentrates the solutes (including urea, uric acid, creatinine), leading to a darker colour of urine. After fluid ingestion less water needs to be reabsorbed to maintain homeostasis so larger quantities of pale urine are produced.

What the evidence says

We found eight low quality studies published with no systematic reviews. As there is no objective measure of hydration, all of these studies compared urine colour to surrogate markers: none directly investigated the correlation between urine colour and performance or the correlation between urine colour and thirst. The results are divided. Three studies recommend urine colour as a tool to roughly estimate hydration status, albeit when accurate results are not required or other assessment tools are not available,[5-7] while three conclude urine colour is too inaccurate to be useful.[8-10] Two further studies suggest urine colour can be useful but only in specific situations (such as first morning void) or in combination with other measures of hydration such as body mass.[11 12]

The three studies that support the use of urine colour include several caveats: vitamins and medicines interfere with the results by making urine darker,[13] variations in diet and dietary supplements affect accuracy, and, if large volumes of hypotonic drink are consumed following exercise,[10 14] copious volumes of dilute urine will be produced before normal hydration is achieved.[15] Despite this, no study has looked at the correlation of urine colour with hydration when different fluids are used for rehydration.

None of the eight studies looked at the correlation between urine colour and overhydration. This important oversight makes it difficult to recommend urine colour as a safe hydration assessment tool: attempts to produce pale or straw coloured urine may go too far, potentially leading to overhydration and hyponatraemia.[16] Many of the studies recommend a stopping point, often using the 8-point scale to assess urine colour described by Armstrong and colleagues.[5] but this seems to be based on speculation rather than research.

Finally, one study showed that 66 people were less reliable at distinguishing their urine colour than trained investigators.[16]

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However, all eight trials used trained investigators to interpret urine colour but they were unblinded to the results of other measurements of hydration status. This alone seriously undermines the use of urine colour for assessing hydration. In the practical sports setting it is likely to be misleading.

You should drink before you feel thirsty

The website for sports drink Gatorade says "Your brain may know a lot, but it doesn't know when your body is thirsty. You need to drink during exercise before you feel thirsty in order to get enough fluids in your body to maintain your performance level" (wardmulroy.com/gatorade/DOCS/4/content(13).html). Powerade advises customers that "To avoid dehydration … you should drink before, during, and after sport" and that, "You may be able to train your gut to tolerate more fluid if you build your fluid intake gradually" (www.powerade.com.au/Sports-Hydration/Using-Powerade-for-Training-and-Competition.html).

Science behind the claim

When the body loses fluid due to sweat, the extracellular concentration of sodium rises leading to a subsequent increase in osmotic pressure and intracellular dehydration. Osmoreceptors in the hypothalamus detect dehydration and signal other parts of the brain to stimulate the sensation of thirst.[17] In extreme conditions such as malnutrition[18] or when children are left in hot cars[19] failure to react to thirst sensations by consuming fluid can have fatal consequences.

Drinking too much leads to other potential problems. If the body takes in more water than the kidneys can excrete, body solutes become diluted. Hyponatraemia occurs when the sodium concentration in the blood drops below 136 mmol/L.[20] The effects of hyponatraemia range from mild (asymptomatic) to fatal.[21]

What the evidence says

One systematic review of the effects of glycerol induced hyperhydration on fluid retention and endurance performance in long cycling time trials found performance was maintained provided loss of body water is kept between 1.8% and 3.2% of body weight (roughly 1.5 L of sweat for a 60 kg human).[21]

A more recent systematic review of the effects of exercise induced dehydration on performance in long cycling time trials suggested that drinking according to thirst sensations (as opposed to drinking more or less frequently) was associated with better sports outcomes.[22] One of the studies in the review found that exercise induced dehydration of up to 2.3% of body weight significantly improved performance.[23] The explanation for how exercise induced dehydration might improve performance is straightforward: you carry less weight, and you don't have to interrupt your exercise.

Although we could not find a report in the medical literature of dehydration being a direct cause of death in marathon runners, we did find overhydration was responsible for several deaths.[24 25] By following advice to "drink before thirst," many athletes are drinking too much, which does not help performance and puts them at risk. A recent study of 88 participants in the London marathon found that 11 (12.5%) developed asymptomatic hyponatraemia.[26]

Energy drinks with caffeine and other compounds improve sports performance

Drinks manufacturers claim that "Stimulants such as caffeine, guarana and taurine with energising fast and slow release carbohydrates produces a scientifically proven range designed to enhance your overall performance (www.maxifuel.com/maxifuelranges/focus). Red Bull says "In extensive studies it has been repeatedly proven that Red Bull increases performance" (www.redbull.co.uk/cs/Satellite/en_UK/Red-Bull-Energy-Drink/001243026254412).

Science behind the claims

Caffeine has long been used to enhance sports performance,[27] and energy supplements containing caffeine, in addition to other compounds, are purported to be uniquely performance enhancing when taken together. These include taurine, a sulphonic amino acid that is thought to increase skeletal muscle contractility while decreasing systemic vascular resistance[28 29]; and guarana, which contains caffeine and related xanthines.[30] Caffeine acts as a competitive inhibitor of adenosine on central nervous system receptors,[31] and an inhibitor of phosphodiesterase.[32] It increases heart rate and induces glycogen sparing,[33] and is believed to enhance available energy stores.

What the evidence says

One systematic review of adding caffeine to carbohydrate [34] and several other reviews of caffeine alone[35-38] suggest that it enhances endurance performance, with these effects being most marked after at least seven days' abstinance from caffeine.

We found nine randomised controlled trials investigating the effects of caffeine energy drinks.[39-47] Four trials recruited the general public[39 41 43 46] and five trained athletes.[40 42 44 45 47] Seven tested a caffeine energy drink in addition to guarana and/or taurine.[39-41 43-45 47]

Four studies reported positive effects: a study of 15 "healthy young adults" reported an energy drink increased mean bench press repetitions, but not anaerobic peak or average power during a cycling test.[43] Aerobic and anaerobic endurance was increased in 14 habitual caffeine users[39] and two trials demonstrated improved endurance in trained athletes.[45 47]

Three studies found energy drinks did not improve sports performance: for running time to exhaustion among physically active university students,[41] mean sprint time among female collegiate soccer players engaged in repeated running trials,[40] and sprint performance or anaerobic power in American college football players.[44]

Two studies tested the effect of a caffeine-only energy drink and did not include other supposedly performance enhancing compounds.[46 47] One study of a caffeine-taurine energy drink reported its effect on echocardiographic findings and did not report sports outcomes.[48]

We did not find any research comparing the effectiveness of energy drinks versus caffeine alone on sports performance.

On the negative side, effects of caffeine consumption can include insomnia, headache, and gastrointestinal bleeding.[27] The harms of energy supplements include nausea and vomiting, tachycardia, tremors, seizures, and sleep disturbances, particularly in adolescents.[49-51] There are several reports of cardiac arrhythmia and death,[50] as well as reports of adolescents requiring hospital admission as a result of consuming energy drinks.[52]

We could not identify any research that assesses the additional benefit energy drinks provide in addition to moderate caffeine

Bottom line: urine colour as a measure of hydration

General public—Evidence is lacking to suggest that urine colour is a useful, safe, or accurate marker of hydration

Professional athletes—Limited evidence to show that first morning urine colour can be reliably used to assess dehydration and rehydration

Required research—A high quality study evaluating the use of urine colour in detecting hydration with blinding of participants and researchers to other assessment tools when measuring urine colour. Ideally this should look at the relation between urine colour and other markers of hydration including thirst and body mass

Bottom line: drinking ahead of thirst

General public—Drinking ahead of thirst may worsen performance in endurance exercise and carries a rare but serious risk of hyponatraemia. The body's internal mechanism for staying hydrated is cheaper, easier, and seems to be the best way to optimise performance

Professional athletes—Elite endurance athletes perform best when they drink to thirst; some studies suggest exercise induced dehydration can improve performance

Required research—A high quality randomised trial measuring the performance effects of different hydration regimes during shorter exercise (sprint-type) would determine whether the results of systematic reviews are generalisable beyond endurance athletes

doses, and we found no systematic reviews of these products and sports performance.

Carbohydrate and protein combinations improve post-workout performance and recovery

"The combination of protein and carbohydrates has been shown to stimulate increased uptake of glucose by the cells, resulting in faster glycogen storage compared to carbohydrates or proteins alone (www.myprotein.com/uk/products/recovery_evo)."

Science behind the claims

After exercise, 24 hours of rest are usually sufficient to replenish glycogen stores alongside a regular diet.[53 54] Ingesting carbohydrate during recovery from exercise may improve subsequent sports performance by increasing the rate of glycogen synthesis.[55 56] However, combined ingestion of both protein and carbohydrate has been shown to synergistically influence the release of insulin,[57 58] increase the rate of muscle glycogen storage,[59] and reduce markers of exercise induced muscle damage.[56]

What the evidence says

We identified 21 trials (15 randomised with 322 participants), of which fewer than half reported an overall benefit of combined protein and carbohydrate compared with carbohydrate alone. One systematic review concluded that the available evidence fails to show a relation between increased muscle glycogen synthesis and improved sports performance.[54]

Studies varied considerably in the outcomes and the ratio of carbohydrate to protein used: from 2:1 up to 6:1. Four studies that evaluated the effects of a 2:1 ratio on cycling performance were inconclusive.[60-63] A 2006 study reported no difference in total distance cycled with supplementation, but two years later the same group reported the effect was significant.[60 61] Similarly, another group found added protein improved sprint cycling performance in men 60 hours after exercise but not at 15 hours after exercise.[62 63]

The five studies evaluating a 4:1 protein to carbohydrate ratio had contrasting results.[64-68] Only one study evaluated performance in a competition and reported no change in cross-country race times.[66]

Four of six studies[69-74] evaluating a 3:1 ratio, used an isocaloric control, enabling comparison between two products of the same caloric content.[69-73] Two reported improved cycling performance[69 71] while the other two reported no change in running time to exhaustion or performance tests for football players.[70 71] The improvement reported in the most recent study was trivial: a small increase in mean sprint cycling power of 2.5% with overlapping confidence intervals.[69]

One study evaluated a 6:1 ratio and found no change in running time to exhaustion in 16 recreationally active men.[75]

Experts have suggested there is little additional benefit of protein in supplements when carbohydrate is ingested in adequate quantities (≥1 g/kg/hour).[57] If carbohydrate content reduces to below 1 g/kg/hour, then adding protein will produce similar results to carbohydrate alone.[57] We found little consistent evidence across all included studies to support this claim.

Six studies looked at whether carbohydrate and protein improved muscle recovery.[72 76-80] Only one found that carbohydrate and protein after exercise induced muscle damage resulted in smaller decreases in muscle performance (such as. knee flexion repetitions) compared with carbohydrate alone.[80] However, the main findings were post hoc analyses, and two follow-up studies failed to definitively replicate the findings.[78 79] Three further studies looking at similar measures found no effects on muscle recovery.[72 57 77]

The lack of benefit from protein supplements on performance or muscle is probably due to the fact that most athletes consume adequate amounts of protein in their diets.[81]

Branched chain amino acids improve performance or recovery after exercise

Pure branch chain amino acids are claimed to help hard training athletes recover faster after intense exercise, combat muscle damage during exercise, and support peak endurance performance (www.maxifuel.com/bcaas). Manufacturers also maintain that they can "help to sustain a healthy immune system during periods of intense training and play an important role in fatigue and performance" (www.maximuscle.com/viper).

Science behind the claims

Branched chain amino acids (leucine, isoleucine and valine) are termed essential amino acids because they cannot be synthesised by humans and therefore have to obtained from the diet. They are incorporated into all protein structures and are an essential precursor for muscle protein.[82] Muscle fibres are disrupted during exercise and essential amino acids are therefore required for repair, remodelling, and synthesis.[83] Ingesting excess branch

Bottom line: energy drinks containing caffeine and other stimulants

General public—Low quality evidence supports the use of energy drinks containing caffeine, taurine, or guarana to improve acute strength performance and aerobic and anaerobic endurance. No studies compare the effectiveness of these products with ingesting caffeine alone and there are important concerns regarding harms

Professional athletes—Limited, low quality evidence supports the use of energy drinks containing caffeine, taurine, or guarana to improve endurance in moderate intensity activity of around 60 minutes. No studies compare the effectiveness of these products with ingesting caffeine alone and there are important concerns regarding harms

Required research—High quality randomised trials in real-world settings evaluating the comparative effectiveness of energy drinks and caffeine alone on sports performance

Bottom line: protein and carbohydrate supplements

General public—There is a lack of evidence to support combined carbohydrate and protein supplements after exercise to improve recovery and reduce muscle breakdown

Professional athletes—The results of studies of supplements containing a variety of carbohydrate to protein ratios show inconsistent and generally small benefits in some measures of sports performance, but generally do not show benefits over and above a balanced and nutritious diet

Required research—High quality randomised controlled trials evaluating specific ratios of carbohydrates and proteins that are adequately powered to detect a meaningful increase in subsequent sports performance

chain amino acids around the time of exercise is proposed to ensure maximum availability for synthesis of muscle.[84] High blood levels of amino acids stimulate insulin release, which also promotes muscle synthesis. They also increase the activity of the mTOR (mammalian target of rapamycin) pathway, which regulates muscle cell growth and protein synthesis.[83]

What the evidence says

We found two systematic reviews; one did not report the inclusion criteria and the search strategy was poor quality,[85] and the other concluded that any performance improvement was due to the energy value of the amino acids rather than muscle protein metabolism.[86] We identified 27 randomised controlled trials, of which 20 (with 6-41 participants) measured athletic performance or recovery. There was no consistent use of objective measures for athletic performance or recovery and adverse effects of amino acid administration were not recorded across studies.

Crossover studies, which used a single dose of amino acids at the time of exercise testing, found no effect on work done during cycling sprints,[87] distance travelled in a cycling time trial,[88] maximum oxygen consumption,[89] or time to exertion during cycling,[90] and no effect was seen in parallel group studies on running to exhaustion[91] or strength during squat weight lifting.[92]

Trial designs with longer durations of amino acid supplementation showed variable effects. One trial showed no effect over the course of a 32 hour yachting race on hand grip strength and vertical jump height.[93] Studies using amino acid supplementation of up to one week reported no effect on cycling sprint power[94] but found small increases in maximum oxygen consumption,[95] increased time to exhaustion,[96] and increased hand grip strength.[97] Supplmentation for more than three weeks alongside regular weight training had no effect compared with standard protein on maximum leg and bench presses,[98] but compared with placebo increased leg strength,[99] upper body strength,[100 101] and rowing time to exhaustion.[102]

Short term ingestion of branched chain amino acids reduced perceived exhaustion at the time of testing independently of changes in performance. Significant reductions in fatigue have been reported in studies over the first hour of exercise,[86] a reduction of 2.9 points on a 16 point exertion scale at 90 minutes[87] and a 2.6 point difference on a 20 point scale at 120 minutes after exercise.[103] Studies of longer term supplementation also showed subjective mean improvements on a 0 to 10 cm visual analogue scale (VAS) of 1.1 cm,[104] small improvements on arbitrary indices from a VAS 12, and a difference of 2 points between BCAA and placebo on a 15 point scale.[101] Amino acids significantly attenuated the reduction in leg flexion torque and maximal isometric leg muscle contraction observed in the placebo groups.[105 106]

Three trials reported the effect of amino acids on delayed onset muscle soreness after exercise. Amino acids significantly reduced muscle soreness by 1.2 points on a 10 point scale at 24 hours after endurance training[105] but had inconsistent effects after intensive squats, with one trial showing no effect over 72 hours[91] and another showing a reduction of 2 points on a 10 point scale at 24 hours.[106]

Trials with a high risk of bias that use longer term supplementation report improved athletic performance under laboratory conditions. All trials reporting subjective measures of endurance showed positive effects, irrespective of objective measures of performance.

Compression garments improve performance or enhance recovery

"This ultra-tight, second-skin fit delivers a locked-in feel that keeps your muscles fresh and your recovery time fast" (www.underarmour.com/shop/uk/en/mens-coldgear-action-legging/pid1000525).

Science behind the claims

Sports compression garments are made of body hugging fabric that exerts various degrees of pressure and are designed to be worn next to the skin. They can cover the entire body or only the lower or upper halves.

Wearing compression garments during exercise is thought to improve venous return and increase removal of metabolites such as lactic acid. Additionally the garments are claimed to work by reducing the oscillation (or "wobble") of muscles and tendons that occurs during repetitive exercise, thus reducing muscle pain and fatigue. By reducing damage the garments may reduce the predisposition to serious injury later.[107] Finally, for contact sports such as rugby or American football, compression garments may cushion direct trauma to the body.[107]

Bottom line: branched chain amino acids

General public—High quality evidence is lacking that branched chain amino acids enhance performance or recovery

Professional athletes—There is no evidence that branched chain amino acids enhance performance in competitive settings. There is limited evidence to suggest that muscle soreness and recovery may be reduced and that longer term supplementation may increase some strength and endurance measures

Required research—High quality large randomised trials evaluating the effect on outcomes that are directly relevant to athletes, such as run times or maximal weight lifts in the competitive setting

What the evidence says

We identified three trials that examined the effect of compression garments on actual sporting performance measures, all of which had negative results. One study of cyclists found no difference in 1 hour time trial performance,[108] and two studies of runners found no significant difference in 10 km time trial performance or lactic acid levels.[109 110]

A further 10 studies found no benefit from compression garments on various exercise protocols in controlled or laboratory settings. This included treadmill running or sprinting performance,[111-115] performance in a netball specific circuit,[116] cricket players' sprinting performance and ball throwing distance,[117] sprinting performance or lactate levels in hockey players,[118] and tests on speed, aerobic endurance, agility, or power.[119] Finally, a small study of cycling on ergometers found participants wearing compression stockings had significantly higher blood lactate levels at the end of exercise period and during the recovery period.[120]

Four studies reported improvements in exercise performance and reduced lactic acid levels in participants wearing compression garments; however, effects sizes were generally small.[121-124]

In terms of recovery from exercise, one study found compression substantially improved performance in a 40 km cycling time trial by a mean of 1.2%.[125]

Six studies reported a beneficial effect of compression garments (worn during or after exercise) on muscle soreness in runners,[109 110] cricket players,[117] weight lifters, general sprinting and jumping exercise session,[126] untrained women doing arm exercises,[128] and rugby players.[127] Of these, three reported significantly lower levels of creatine kinase in the compression groups, a surrogate marker of muscle damage.[117 126 128]

Finally, three studies that compared recovery using compression garments to other forms of recovery treatment (such as massage, hot and icy cold water therapy, low intensity exercise) found that all strategies were better than nothing but that compression garments had similar effects to those of these other treatments.[107 129 130]

Several studies have found that compression garments increased skin temperature compared with normal clothing. Although the single study that examined core temperature was done in cool conditions,[118] it found no effect on core temperature. But for exercise in hot or humid environments, the alteration of normal skin thermoregulation could be important. One study of compression garments noted a reduced range of motion of the hips during exercise.[119]

Competing interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years, no other relationships or activities that could appear to have influenced the submitted work.

Provenance and peer review: Commissioned; externally peer reviewed

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Bottom line: compression garments

General public—There is a lack of evidence to support use of compression garments to improve sporting performance. They may reduce muscle soreness if worn for 24 hours after an exercise session

Professional athletes—There is no consistent evidence that compression garments improve sporting performance. Muscle soreness seems to be reduced if garments are worn for 24 hours after exercise, but objective measures of recovery are less consistent, and compression garments seem to work no better than other recovery strategies such as low grade exercise or contrast bathing. Potential adverse effects of these garments may include increased skin temperature, decreased thermoregulation, and reduced range of motion

Required research—Larger studies in individual sports and research generalisable to either highly trained athletes or the general population, with outcomes related to sports performance, and examination of adverse effects and acceptability of compression garments

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Cite this as: *BMJ* 2012;345:e4848