In a previous blog post I set about analysing the physiological and nutritional requirements of a triathlete, and discussed the application of carbohydrate feeding during such endurance exercise. I critically analysed the efficacy of the carbohydrate content of existing sports drink formulations and went on to give specific recommendations based solely on the carbohydrate content.

In this blog post I will go on to discuss the efficacy of other ingredients that are now often included in sports drink formulations. These added ingredients often add to the confusion when choosing sports drinks, and are marketed as ergogenic (performance enhancing), but are they? Let’s find out.

As discussed last week, the primary constituents of a sports drink are carbohydrate, water and electrolytes. The carbohydrate content provides a source of energy and serves to delay the onset of fatigue, which during prolonged exercise is associated with muscle glycogen depletion and reduced blood glucose concentrations. The water content prevents
dehydration resulting from increased sweat losses, which can also impair endurance performance. The electrolyte content serves to replenish those lost through sweat during exercise.

Sodium retention is tightly regulated by the renin-angiotensin-aldosterone system, however under certain circumstances where large sweat sodium losses occur, typically in ultra endurance events, or where the consumption of fluid exceeds sweat loss, or fluid is replaced with low sodium beverages mild hyponatremia can ensue. Therefore sports drinks that include sodium in concentrations of 0.5 – 0.7 g/L of fluid (21 – 30 mmol/L) are recommended (1). The replacement of electrolytes during and after exercise is also useful for maintaining the thirst drive, and sodium concentrations of between 10 – 25 mmol/L enhance the palatability and voluntary consumption of fluids consumed during exercise. Most athletes’ electrolyte requirements are sufficiently provided by a balanced diet, although in prolonged endurance events replenishment through sports drink consumption is necessary. Interestingly a rehydration study following an exercise-induced loss of 2.5% body weight, subjects exhibited greater plasma volume recovery and lower urine volumes when they ingested chicken broth and chicken noodle soup as opposed to a traditional sports drink (2).

So in actual fact, post-race, a normal mixed meal would be sufficient in restoring electrolyte balance, so the electrolyte content of sports drinks is often over-exaggerated. That said, in longer duration events such as the ironman electrolyte replenishment maybe necessary.

Caffeine

The capacity of caffeine to enhance muscular performance was first realised over 100 years ago. A number of manufacturers now incorporate caffeine into their sports drink and gels formulations owing to it’s ability to stimulate the central nervous system, heighten alertness and focus, with metabolites of caffeine known to result in vasodilation and smooth muscle relaxation. Caffeine-mediated increases in oxygen uptake, catecholamine release and metabolic rate have also been reported, along with reduced perceived exertion.

A review concluded the mean improvement in endurance time-trial performance with caffeine ingestion was 3.2 ± 4.3%, although the authors did report a high degree of variability thought to result from a variety of factors including time of ingestion, ingestion mode, and subject habituation (3). Either way research comprehensively indicates caffeine in doses between 3 – 6 mg.kg body mass consumed approximately 1-hour before exercise augments endurance exercise performance. Despite popular belief the ergogenic effects of caffeine are similar in both non-habitual and habitual caffeine consumers (4) and 4-days of abstinence had no effect on the ergogenic effect of caffeine during time-trial performance (5).

Caffeine is completely absorbed 45-minutes after ingestion, with a half-life of 3 – 4 hours, so ingestion pre-exercise is warranted, although it’s ability to reduce perceived exertion makes ingestion during prolonged exercise advantageous. Manufacturers commonly include caffeine in doses of 50 – 100mg in sports drinks and gels, meaning the average 70kg triathlete would require anywhere between 2 and 8 gels or drinks to obtain the optimal dosage, so perhaps lone caffeine supplementation in the form of pro plus would be a more effective method.

Interestingly, High5 who produce EnergySource, which I recommended in the last article based on its favourable carbohydrate content also produce an EnergySource Xtreme, which boasts 47g carbohydrate per 50g sachet and a caffeine dosage of 150mg per 50g sachet. Ultimately, of all the existing formulations this product provides the most scientifically supported carbohydrate and caffeine content, where at the required rate of carbohydrate intake (at most 2 sachets per hour) you will also obtain an ergogenic dosage of caffeine (300mg), doff my hat to High5 again. Alternatively, two tablets of pro plus contain 100mg of caffeine.

Nitrates

Under hypoxic conditions (strenuous exercise) nitrate and nitrite is reduced to nitric oxide, which is known to have several effects on aerobic energy turnover in humans. Nitric oxide is a vasodilator, and appears to play a role in the regulation of oxygen delivery to the working muscles (6).

It is believed the increase in nitric oxide following nitrate ingestion reduces the oxygen cost of exercise through enhanced muscle efficiency by reducing the energy cost of contraction or enhanced mitochondrial efficiency – or both. Research
indicates a dose of 300mg nitrate results in a peak in plasma nitrate within 2 – 3 hours, and reduces the oxygen uptake during steady-state submaximal exercise reflective of triathlon performance in club level, moderately trained subjects (VO_{2max} > 50 ml/kg/min).

However, much of the existing evidence suggests that these results are not replicated in trained, elite subjects (VO_{max} < 65 ml/kg/min), with speculation that highly trained subjects already have optimal nitric oxide synthetic capabilities, making exogenous nitrate supplies useless (7).

A number of manufacturers include nitrate in dosages close to the required active dose of 300mg in their respected drinks, gels and shots. Science in sport for example includes a dosage of 250mg nitrate per Go gel + nitrate product, this combined with a carbohydrate dosage of 20g, not exactly optimal in regards carbohydrate dosage. The evidence appears to suggest these products are only effective in untrained, or moderately trained individuals; further studies are required to confirm this. It also appears that chronic as opposed to acute ingestion is required to optimise the ergogenic effect.

Carnitine

Carnitine is a naturally occurring acid that can either be synthesised or consumed from dietary sources. L-carnitine plays an important role in enabling the transport of long-chain fatty acids across the otherwise impermeable inner mitochondrial membrane. It is hypothesised that increased availability of L-carnitine will increase the capacity to transport and oxidise fatty acids in the mitochondria, posing significant benefit to endurance athletes.

This mechanism has been demonstrated in vitro, with elevated free-carnitine pools raising long-chain fatty acid oxidation by the mitochondria (8). The issue in vivo however exists in delivery of carnitine to the muscle across a large concentration gradient, where even substantial oral intakes will not result in measurable alterations in muscle carnitine concentrations. This would explain the comprehensive level of data showing no ergogenic effect of acute L-carnitine ingestion on metabolism or endurance performance (9).

Interestingly however, a recent study has demonstrated that combined hyperinsulinaemia, in the presence of hypercarnitinaemia can augment muscle carnitine content by approximately 14%, through increased Na^+/K^+ pump activity. The same lab went on to discover 24-weeks of L-carnitine supplementation in a dosage of 1.36 g/day, combined with a carbohydrate solution 160 g/day increased muscle carnitine stores by 21%, resulting in an increase in power output during the performance trial of 11% from baseline. Performance was not different between groups at 12-weeks of supplementation (10).

So methods of increasing skeletal muscle total carnitine content have been uncovered, although further research is required as current methods are not without their limitations. Either way, an acute dose of 2 g L-carnitine as found in popular sports drinks and gels will be ineffective. Again, science in sport are guilty of ignoring the existing evidence by including a dosage of 1g carnitine per Go gel + carnitine product.

Protein and/or amino acids

A number of sports drinks now contain protein or individual amino acids, typically in 4:1 ratio carbohydrate to protein, with some reports of enhanced performance in endurance exercise following consumption of sports drinks providing protein/amino acids compared to traditional carbohydrate-electrolyte formulations. The case for the consumption of drinks with combined protein and carbohydrate in the recovery period after exercise is strong, although the benefit of such drinks during exercise are contentious.

A meta-analysis explored the influence of protein ingestion during exercise on subsequent endurance performance suggested a methodological bias exists, only 3 of the qualifying studies were time-trial protocols, relevant to competitive triathlon performance, and only 3 controlled for caloric content and contained an isocaloric trial (11). The 3 time-trial protocols reported no significant improvement with protein ingestion. Studies that controlled for caloric content revealed a performance improvement of just 3.4% although not all of those were time-trial protocols, some were time to exhaustion. The authors concluded that compared to carbohydrate alone, co-ingestion of protein and carbohydrate during exercise enhanced the performance of time to exhaustion protocols, and also when supplements were matched for carbohydrate.
Thus, the ergogenic effect of protein seen in such studies may be because of a generic effect of adding calories (energy) as opposed to a unique benefit of protein.

Many have also suggested that BCAA ingestion during exercise may attenuate central fatigue and thus enhance endurance performance. Central fatigue is believed to occur when alterations within the central nervous system (CNS) decrease the ability to voluntarily send a signal to a neuromuscular junction and thus stimulate muscular contraction.

The central fatigue hypothesis predicts that the ingestion of BCAA’s during exercise will raise plasma BCAA concentrations and thus reduce the transport of free tryptophan into the brain; subsequently reducing the synthesis and release of the neurotransmitter serotonin and alleviating sensations of fatigue, therefore improving endurance performance (12). Although this mechanism makes good intuitive sense and fatigue during prolonged exercise is clearly influenced by a complex interaction between peripheral and central factors, the hypothesis lacks significant support and little is known about the mechanisms underlying CNS effect on fatigue through the obvious difficulty of studying an intact human brain (13).

Ultimately however, existing research has suggested that to be physiologically effective in reducing central fatigue, large doses of BCAA’s are probably required. Large doses are likely to increase the ammonia concentration in plasma, which is known to be toxic to the brain and muscle. It has also been suggested that buffering of ammonia could lead to early fatigue in working muscles by depleting glycolytically derived carbon skeletons (pyruvate) and draining intermediates of the tricarboxylic acid cycle. Large doses of BCAA during exercise may also slow, or impair water absorption across the gut, causing gastrointestinal disturbances.

**Medium-chain triglycerides**

Skeletal muscle contraction is fuelled by fat and carbohydrate during exercise, with fat being quantitatively the most important fuel for endurance exercise such as triathlon. Glycogen, particularly muscle glycogen is an important fuel if higher intensities are required – during a sprint finish in a triathlon perhaps. Body glycogen stores are small (8 to 16 MJ) and can be depleted within 60-minutes, whereas fat stores are extremely large even in very lean triathletes (192 MJ in an 80kg person with 15% body fat). Any adaptation that may preserve carbohydrate stores and increase fat oxidation can therefore enhance endurance capacity.

Medium-chain triacylglycerols (MCT's) are composed of fatty acids with a chain length of 6–12 carbons, MCT’s bypass the lymphatic route and travel rapidly into portal circulation via passive diffusion, which make it a readily available energy source. The unique metabolism of MCT's has resulted in great interest in the effects of these fatty acids on exercise performance, and to some manufacturers including MCT’s in their sports drink and/or gel formulations.

A comprehensive review of the effects of MCT ingestion during exercise on endurance performance was completed in 2004, studies including dosages between 30 – 116g MCT, timing of ingestion ranged from 1-hour pre-exercise and at 15-minute intervals during training, duration of exercise ranged from 120 – 180-minutes and intensity ranged from 57 – 60% VO_{2}\text{max} (14). Only one of the 8 trials included showed a performance improvement and reduced glycogenolysis with MCT, and adverse gastrointestinal effects occurred at dosages greater than 50g MCT. More recently, and more relevant to triathlon performance, a group of cyclists ingested 200ml of a 10% carbohydrate solution or one containing 4.3% MCT and 10% carbohydrate every 20-minutes. Time-trial performance was significantly slower in the MCT trial and half of the subjects experienced adverse gastrointestinal discomfort (15).

I'm not aware of any existing products or manufacturer that include MCT's within their formulation, although historically there have been a few examples. It appears that most manufacturers have, based on the existing evidence aborted all hope of an ergogenic effect of MCT in sports drinks.

Having critically analysed a number of the added ingredients included in popular sports drinks and gels it is evident that only caffeine is currently of proven benefit beyond the typical carbohydrate, electrolyte and water formulation. Nitrate containing formulations could be advantageous to untrained athletes in the dosages typical of existing formulations, while L-carnitine would be ergogenic if it could be effectively delivered to the muscle. Further research is required to illustrate the
role of protein during exercise, and perhaps develop upon the role of BCAA’s in the central fatigue hypothesis, while MCT’s quite conclusively offer no performance benefit and could potentially negate performance.

Based on this evidence I would again point you towards High5’s EnergySource product, either the lone EnergySource product with a dosage of pro plus or the EnergySource Xtreme product, which boasts additional caffeine. As with all performance nutrition strategies, I would advise you err on the side of caution and practice consuming the above products in training prior to using them in competition – just in case.

References


I critically analysed the efficacy of the carbohydrate content of existing sports drink formulations and went on to give specific recommendations based solely on the carbohydrate content. In this blog post I will go on to discuss the efficacy of other ingredients that are now often included in sports drink formulations. These added ingredients often add to the confusion when choosing sports drinks, and are marketed as ergogenic (performance enhancing), but are they? Let's find out. As discussed last week, the primary constituents of a sports drink are carbohydrate, water and electrolytes. Inspired by the thought of all the sports drinks that will be consumed during the upcoming Summer Games in Rio de Janeiro, we were curious to explore the composition of several sample beverages using modular spectroscopy. With an array of ingredients to measure — from food dyes to fruit and vegetable extracts – we opted to build our sport drink setup around the extended wavelength range Flame-S-XR1 spectrometer, which covers 200-1025 nm. By covering this wide wavelength range, we ensured we weren’t missing any interesting spectral features. Overall, the perfect sports drink does not exist. The athlete must consider several factors when choosing a sports drink including the type of exercise to be performed (e.g., if glycogen depleting, carbohydrates should be a main ingredient in the sports drink); duration of exercise; intensity of exercise; tolerability; and of course, the preference of the athlete.53. Sports Nutritionals. Sports nutritionalists, including sports drinks and nutritional bars, and other products such as protein and weight gain powders, supplements for before and after workouts, and energy gels are an increasing trend driven by the consumer demand for healthier, more dynamic sports beverages.