



MODULE 8

SUPPLEMENTATION FOR HEALTH AND PERFORMANCE

8. MODULE 8: SUPPLEMENTATION FOR HEALTH AND PERFORMANCE

8.1. Module aims

- To explain what a supplement is and the context in which they should be used
- To outline the supplements which are commonly used for health and provide some of the contexts in which they could be beneficial
- To describe the supplements used for performance and explain how they could be used
- To introduce students to Examine.com

8.2. Key principles from module 7

In the last module, we took a slight detour away from topics that are more self-evidently central to nutritional study to discuss sleep. While sleep may not be as intrinsically linked to nutrition as other aspects of this course, we hope that you now appreciate that sleep has a direct impact on your overall health and wellbeing; and also that it can have an indirect impact on your weight management (due to its influence over the hormonal drivers towards appetite regulation). You should now understand the manner in which sleep restriction impairs cognition and therefore decision making ability. In module 7 you learned:

- Sleep is an active state caused by your brain rather than something which ‘happens to it’ due to simply becoming periodically fatigued
- Sleep is not a homogenous state, but something made up of 4 different stages – non-REM stages 1-3 and REM sleep. You cycle through these throughout the night, and each stage has unique properties and benefits
- Sleep is mediated by both the circadian rhythm which is governed by the suprachiasmatic nuclei, and the homeostat pathway which is governed by adenosine metabolism in the brain
- Sleep restriction can result in impaired reaction time, cognitive function, hormone secretion, immune function and subjective mood, but can also influence weight management owing to the effects both cause to endocrine drivers of appetite and conscious willpower
- There are a number of ways in which sleep can be improved, from altering the sleep environment to paying closer attention to your sleep hygiene

8.3. Introduction to supplements

In this module, we will discuss the core topics related to nutrition and speak about supplementation. We shall define the term ‘supplements’ and give an overview of the two different categories that we will refer to throughout this module; the distinction between them is important because different people think of different things when the word ‘supplement’ is used.

We will then go in to some broad contexts that may warrant supplement use before taking you through the mechanisms by which certain key supplements perform the role that they do. Finally, we will round this module off by providing you with a means for ascertaining the efficacy of any supplement you come across. This final point is incredibly important because, as you will see, not all supplements and not all supplement claims are produced with the same degree of integrity.

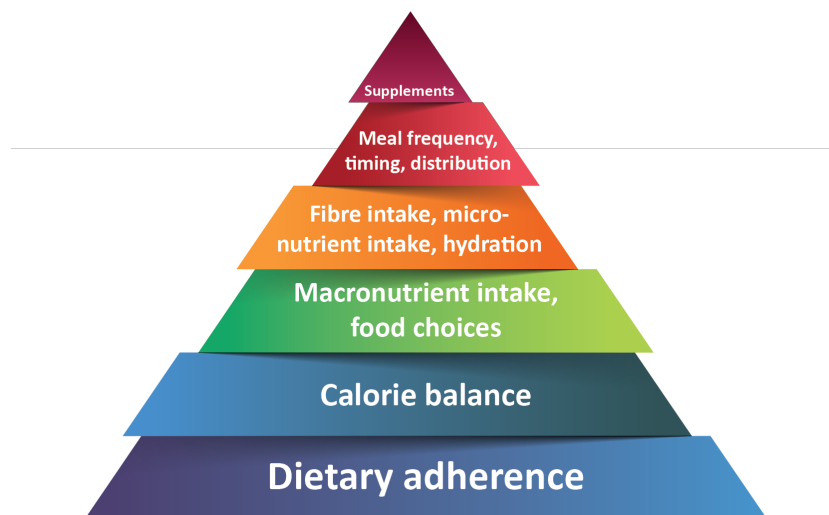
8.4. What is a supplement?

‘A thing added to something else in order to complete or enhance it’.

If you were to attend a public lecture, you would typically receive a handout. This handout would perhaps outline the talk, possibly define some terms and provide a references list so you can fact check what you have learned. This handout is a supplement to the talk: an additional add-on which improves the whole experience to a small yet meaningful degree by providing something not included in the talk itself. This is generally how nutritional supplements should be viewed, too.

Looking back at our hierarchy of nutritional importance you can see that supplements occupy the higher most point of the pyramid. This tells you not only that supplements are the last thing you should think about after everything else has been considered, but that nutritional supplements are likely to make a small difference even when they do make one. If you are currently consuming a diet which contains fewer or more calories than needed, and that is not geared towards your macronutrient requirements, while being low on fibre, you aren’t likely to be as healthy as you could otherwise be, even with the use of a multivitamin or protein powder.

Fig. 81



We are not trying to discourage you from supplement use, but rather we are looking to state from the outset that although supplements often hold some mystique and appear uniquely and disproportionately interesting compared to your vegetable consumption or that extra

half hour of sleep, they aren't. If, however, your current diet is providing almost everything you need in accordance with what has already been covered but it doesn't give you enough calcium, zinc or vitamin D for example, then this small imperfection can be ironed out through targeted supplement use, complimenting and completing the whole.

There is a multitude of ways that supplements can be divided and categorised depending on the situation in which you are discussing them, but for our purposes we will talk about supplements in terms of the two clear categories outlined below.

8.5. The two different categories of supplement

People from various backgrounds who value different things will view and think about supplements in dissimilar ways. An elderly person may supplement with calcium to help them protect their bone mineral density, an athlete may supplement with an ergogenic aid to boost performance and a student studying for a test may take a Nootropic. All of the above are very different products with very different aims but they still fall under the umbrella term of supplements which can be split into two different categories, food and non-food supplements.

These are self-evidently not precise descriptions because a supplement is by definition not a food, and all non-food supplements are derived from foods, food extracts or manufactured versions of food extracts. You will see soon enough why this distinction still has utility. Let's look at what they both mean.

8.6. Food supplements

A food supplement for our purposes of discussion is one which provides a macro or micronutrient which you could in theory get from the consumption of foods in a normal diet. Food supplements typically do not make any grand claims and are somewhat non-controversial provided their usage is decided upon for objective reasons. If your diet is lacking in a certain nutrient then food supplements can bridge the gap.

Examples include vitamin supplements, mineral supplements, protein powders and Omega-3 oils.

8.7. Non-food supplements

Non-food supplements, by contrast, are things which are not traditionally thought of to be provided by food, or things which are in foods but for which the effective dose is exceedingly high. Generally, a non-food supplement would be taken to improve some aspect of health, sporting performance or recovery beyond the level which could be achieved through a normal diet – supplemental creatine for example, falls within this bracket, as do stimulants like caffeine, as both of these improve athletic performance, but the effective dose would not be provided by what could reasonably be considered normal dietary intake of foods. Caffeine could theoretically come from large amounts of strong coffee, but for the purpose of description it falls in this category.

Now we will look in depth at some examples of each. This list is not exhaustive, but extensive, and will encompass most if not all supplements likely to be used under normal circumstances.

8.8. Examples of food supplements

Food supplements are a broad category of products used for a wide range of reasons. Below are the most popular and well-supported examples.

8.8.1. Micronutrient supplements

The most commonly purchased supplements from this category are vitamin supplements. Most of these are relatively straightforward and so we won't dwell too long on these or break them all down individually. Micronutrient supplements are offered in single form, a bundled form to take advantage of combinatorial benefits (for example vitamin D helps with calcium metabolism and so these are often seen together) or as a broad-spectrum multivitamin.

Single vitamin products are the easiest to justify the use of. These products are efficacious when used, to solve a nutritional deficiency caused by incomplete nutrition. If, for example, your diet is low in calcium because you don't consume many calcium-containing foods, then a calcium supplement can help to increase plasma calcium levels and will help you avoid the effects of calcium insufficiency. There is strong evidence for this – for example it has been shown in men who are given a diet which promoted zinc deficiency, that subject sperm count was impacted (zinc is required for sperm production) but subsequent supplementation corrected this issue.

Paired nutrient supplements are also effective, but equally a single micronutrient supplement taken alongside a meal is likely to be consumed alongside other nutrients and, as this is typically the recommended means of taking these supplements, it may not be necessary to spend the extra money.

Broad spectrum multivitamins are an excellent 'safety net' or 'insurance policy' in that they can be taken alongside a normal diet in to avoid micronutrient shortfalls. These have not been shown to be harmful in any way by long-term research, and their mechanism of action is clear. Taking a broad-spectrum multivitamin is something worth considering unless your diet is extremely varied and all-encompassing.

As mentioned in module 3, micronutrients are extremely important and a deficiency in one can have effects more wide-reaching than might be expected, so using supplementation to avoid this could be wise. What is important to bear in mind for the context of this module, however, is that micronutrient supplements do not improve any marker of health per se. It can often be claimed that certain vitamins or minerals will 'boost your immune system' or 'improve skin tone' but it's important to remember that this only happens to the extent that the ideal intake of a nutrient (as defined in module 3) would cause anyway.

This is critical – micronutrient supplements do not cause benefits, they simply allow you to ensure a sufficient intake. Therefore, you get the inherent benefits of the thing you are supplementing. Ingesting amounts over and above what is useful does not give anything more, and in fact supplementation of certain nutrients (most notably trace minerals and vitamin A) which results in an excessive intake can lead to harmful effects so high-dose supplementation beyond what is stated in module 3 is not recommended. If you are concerned that you may be deficient in a certain nutrient, a blood test from a GP will enable

you to find out. For a less invasive approach a micronutrient tracking app should be able to help you pinpoint shortfalls in your regular diet.

8.8.2. Protein powders

These are one of the most popular products currently on the market and arguably for good reason. An adequate protein intake, as you have learned, leads to almost innumerable benefits compared an inadequate one and protein powders can play a role in allowing you to get all you need.

The most common form of protein powder is whey protein, with other milk based products, egg, soy and vegan alternatives making up the rest of the market. In order to choose between the various options, it can be worth considering the Biological Value (BV) of the powders. BV is a measure of the proportion of absorbed protein from a given source which is incorporated into bodily proteins, measured by comparing the amount of nitrogen (which you will remember is a part of amino acid structure but not the structure of monosaccharides or fatty acids) in the protein, with the amount of nitrogen excreted after consumption in a fasted state, to work out the amount of nitrogen retained. If nitrogen has been excreted then amino acids have been broken down to make something else, whereas retained nitrogen implies retained amino acids. The percentage of stored amino acids is then used to create a score.

This is an imperfect scale (the measurements are not 100% accurate, and the BV would likely change from person to person, and even within the same person after eating other things they become altered at different overall protein intakes) but it's a practically useful metric for determining which protein powder is likely to provide the most nutritional benefit.

Egg protein (from whole egg) is typically used as a baseline as it has a very high level of essential amino acids, and almost all of its nitrogen is retained. This makes it the perfect score of 100 against which other proteins can be compared. Below is the BV of the most commonly used protein powders:

- Whey protein concentrate: 104
- Whey protein isolate: 159
- Egg protein powder: 100
- Rice protein: 83
- Casein: 77
- Pea protein: 65
- Soy concentrate: 73
- Milk protein: 91

As you can see, whey-based protein powders win, followed by egg, milk and then the others. Worthy of note, however, are a few key facts:

- Whey isolate supersedes whey concentrate, but a judgement call must be made by the end user. Whey protein has a better than 'perfect' score and is relatively cheap

compared to isolate. The difference between the two in terms of measurable results is going to be negligible to zero, especially being that this is probably not to be your only protein source, and so it wouldn't be wise to opt for whey isolate based on this number alone. Whey concentrate will be 60-80% protein by weight and very low lactose whereas whey isolate will be upwards of 90% and therefore even lower

- Rice and pea proteins are often combined as neither have a perfect amino acid profile which provides all of the essential amino acids in high amounts. The combination of the two would likely increase their BV rather than average it out, though at the time of writing this, it has not been tested
- Egg protein is a great option for those with dairy allergies, but who do not want to opt for a vegan protein which has an inferior amino acid profile and often a higher price point

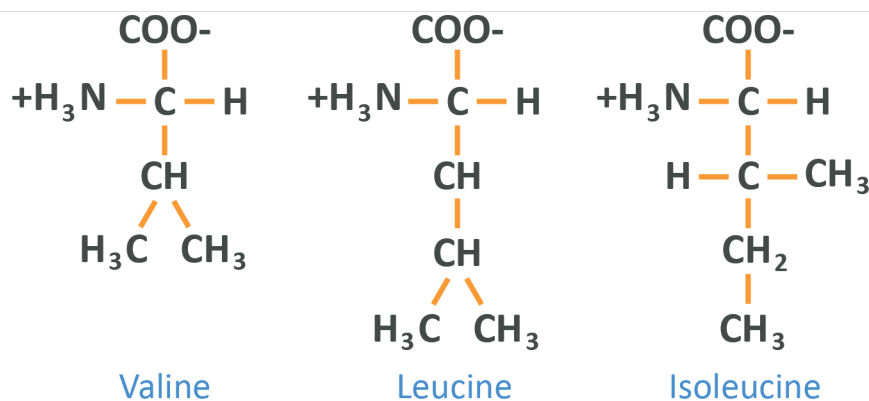
These are, much like micronutrients, nothing more than convenient and affordable options in the search for an adequate intake of regular nutrients. None of them will have any meaningful impact over and above what would be provided by whole food protein sources, and in fact they lack many of the micronutrients provided by the latter. As such, protein powders should not be viewed as a supplement which will provide any benefits per se and nor should it be viewed as an alternative to whole food protein sources.

With that said, these products require no cooking or refrigeration, are relatively cheap and can be enjoyable, so they can be an option alongside an otherwise whole food diet. Consuming an adequate amount of protein throughout the day is key to optimal health and these powders can be considered a viable tool for achieving this.

8.8.3. Branched chain amino acids

Branched Chain Amino Acids (BCAA) are the 3 amino acids leucine, Isoleucine and valine to which you were introduced during module 2. These are referred to as BCAA because their variable side chain has at least 1 methyl group, which you will recall consists of a central carbon attached to 3 hydrogens. This side chain prevents their processing in the liver, and grants them some interesting functional properties.

Fig. 82



Branch chain amino acids make up around 33% of the stored amino acids in the body with the majority of them occurring in skeletal muscle. The key BCAA is leucine, as it is the consumption of leucine which activates the process of muscle protein synthesis. Consumption of proteins containing high levels of leucine create a higher protein synthetic response than a protein with a lower leucine content, and when that leucine content is artificially matched the response is the same. In the search for increased muscle mass, be that for the purposes of bodybuilding, athletic performance or health, this is a very important concept.

Logically it follows that leucine should be used, but this would not result in the ideal situation. All three amino acids are classed as essential, and all are found in high levels in muscle tissue. They serve functions in muscle cells (isoleucine improves glucose metabolism in muscle cells, valine's role is as yet undefined) but their cellular catabolism (breaking down for subsequent use) shares the same two initial steps. Branch Chain Amino Acid Transferases, either cytosolic (expressed in the cytosol – the watery interior of the cell) or mitochondrial, referred to as BCATm and BCATc function to process the three BCAAs and, an overconsumption of leucine can therefore impair the absorption of sufficient isoleucine and valine. The typical ratio of L:I:L:V is 2:1:1 in most foods with a complete amino acid profile and so this ratio is typically adopted for supplementary BCAA, too.

Consumption of BCAAs before training can improve performance during that training session compared to placebo, and post-workout BCAA supplementation can improve recovery compared to placebo. However, these two statements do not necessarily tell the whole story.

BCAA are constituents of whole proteins, and therefore the consumption of a whole protein would have the same effect, provided the same BCAA dosage was consumed (note that, as mentioned, around 3g of leucine will maximally stimulate muscle protein synthesis and so more than this is not necessarily better, regardless of the source). A whole protein would also provide the other essential and non-essential amino acids used to maintain overall positive protein balance and therefore arguably provide more benefit. Ultimately, in those looking to maximise the muscle protein synthetic response from a training session, following the protein distribution guidelines in module 2 – consume protein 3-5 times per day, ensuring you eat something within 2 hours before and after training, rendering BCAA supplementation obsolete.

BCAA have been theorised to reduce soreness, improve recovery and reduce muscle loss during a fat loss phase but, again, this is not supported in any literature.

An argument could be made that supplementation of leucine may be efficacious however. If you regularly consume meals which do not meet the ideal intake level of this amino acid, research indicates that a similar muscle protein synthetic response to whey can be induced by leucine enriched wheat protein (a protein that typically does not stimulate MPS highly). Vegans who consume meals with only one protein source therefore might consider this an option if maximal muscle gain is the goal.

8.9. Carbohydrate powders

Carbohydrate powders are supplemental carbohydrates. They were the first sports supplements produced, thanks to Gatorade – a carbohydrate beverage initially formulated for the American football team, the Florida Gators. Carbohydrate powders come in a multitude of forms, most notably dextrose (pure glucose), maltodextrin (a rapidly digested polysaccharide produced by partially hydrolysing longer starches derived from corn or wheat), fructose, Waxy Maize starch (A starch comprising primarily of amylopectin, the highly-branched form of starch which is easy to digest) or the branded carbohydrate form, Vitargo. Additionally, oat flour can be marketed as a carbohydrate supplement to be added to whey protein, but whether this is a supplement or a food comes mostly down to your perspectives on the definition of both words.

There are four primary reasons for carbohydrate supplementation, namely:

- To increase hydration during or after exercise when consumed alongside supplementary electrolytes
- To maintain steady blood glucose levels during prolonged exercise
- To rapidly replenish used carbohydrates after a workout, to repeat performance
- To increase overall calorie intake

The first three aims are typically catered for by sports drinks which may be hypotonic, isotonic or hypertonic. Tonicity is the measure of relative concentration of a solution, and when talking in terms of sports drinks the concentration against which they are measured is an approximate concentration of carbohydrate and sodium in your blood.

As you have learned throughout this course, blood levels of glucose, sodium and potassium are kept relatively even (with potassium being stored almost exclusively in the intracellular water compartment). This means that the sodium concentration of the liquid exiting the stomach alters the sodium concentration of the blood, and depending on the circumstances this could be an issue. Here are the properties of each drink, and the times that they may be useful:

8.9.1. Hypotonic drinks

These generally contain less than 4g of carbohydrate per 100ml (sometimes zero carbohydrates) and less than 50mg of sodium. This concentration is lower than that in your blood, and therefore not all that useful for replenishing large amounts of lost water and sodium (lost through sweat) nor large amounts of carbohydrates. With that said, these drinks often taste pleasant which promotes voluntary drinking, and the small amount of useful ingredients can give some small boost to daily intake. These drinks are most effective when used simply for refreshment during exercise lasting roughly one hour or less. Typical resistance trainees need not look further if they are going to drink anything at all other than plain water, and the same can be said for typical gym goers who engage in exercise for an hour or less for the purpose of improving general fitness.

8.9.2. Isotonic drinks

These contain 6-8g of carbohydrate per 100ml and 46-51mg of sodium. This is roughly the same concentration as that in your blood and for that reason these are the most popular sports drinks amongst athletes. By consuming an isotonic drink you will replenish electrolytes and water lost through sweat, therefore avoiding the dilution of serum sodium and the associated negative consequences associated. The carbohydrate content of these drinks is also relatively high meaning that they can help to maintain endurance performance for longer – with sports drinks regularly appearing to help improve performance, reduce fatigue and extend time to exhaustion in exercise lasting over an hour.

8.9.3. Hypertonic drinks

These drinks (or gels) generally contain over 10g of carbohydrates per 100ml and are used primarily for the purpose of replenishing depleted glycogen. Typically, they will contain no electrolytes. The high concentration of carbohydrates can slow gastric emptying and therefore delay rehydration and so these should be avoided after training in those who are particularly dehydrated. Consuming a high-carbohydrate drink after a depleting performance will increase subsequent performance significantly if that performance is to be undertaken within a short period of time, but there is no additional benefit to high-carbohydrate intakes from supplements after training if an individual is not training again for 24 hours. By this time interval, normal carbohydrate consumption from food will have replenished what was lost in usual circumstances (ultra-endurance running and other exceptional activities should be taken on an individual basis).

An important thing to note is that each of the above drinks contain calories and those calories matter. Someone looking to lose fat that drinks a high-carbohydrate sports drink during exercise could potentially 'override' the calorie expenditure of the session itself. Sports drinks should be reserved exclusively for individuals looking to improve performance rather than recreational exercisers looking to improve their health through normal amounts of training. However, there is an argument that electrolyte supplementation may be of benefit to those who sweat particularly profusely.

8.10. Which carbohydrate should you use?

The primary reason for carbohydrate supplementation is either to maintain blood glucose levels during training, or to replenish glycogen levels rapidly after training, to recover as quickly as possible. As glycogen depletion is not a factor in the training of most recreational exercisers (and most resistance training athletes) the former is not an issue, and the latter is handled adequately by simply consuming carbohydrates in the meals between training sessions. In short, eating normally with an adequate carbohydrate intake will ensure most individuals have enough stored glycogen to compensate for the activity at hand, and will replenish that which is lost during a training session before the next one.

With that said, for those looking to improve performance over prolonged periods or looking to train intensely more than once per day – carbohydrate powders may be a useful tool. Ingestion of 30-60g of carbohydrates per hour can increase various markers of exercise

performance in exercise lasting up to 2 hours, with dextrose and maltodextrin being the cheapest and yet most well researched forms of carbohydrate capable of having this effect. By combining the two with fructose (which uses a different transporter protein to exit the small intestine and can preferentially replenish liver glycogen, therefore freeing consumed glucose to replenish muscle glycogen and maintain blood glucose), it's possible to increase the 1g of carbohydrate per minute (60 per hour) top level to 1.2-1.75g per minute which seems to be useful for exercise lasting 2 hours or more. Large amounts of fructose consumed at once can lead to gastric upset and should therefore be avoided. Generally, a 1:1:1 ratio, or ratio which emphasises dextrose and/or maltodextrin over fructose is used, with a 1:1:1 ratio having been shown to improve cycling performance over 2 hours incrementally between doses of 10g per hour and 78g per hour before athletes saw diminishing returns.

Two popular, highly priced forms of supplemental carbohydrate are Vitargo and Waxy Maize Starch. The latter has not been shown to be more beneficial than dextrose in that it does not increase blood glucose faster or more efficiently (despite costing a great deal more), but the former does indeed appear to be capable of passing digestion faster owing to its unique structure. It therefore may improve performance in the second workout of a 2-per-day routine more than cheaper carbohydrate forms like maltodextrin or dextrose.

Ultimately the difference is minor but very real, and a cost:benefit analysis should be considered before opting for either a maltodextrin/dextrose/fructose mix or Vitargo alone. Finally, if you are considering using carbohydrate beverages simply to increase your overall calorie and carbohydrate intake throughout the day without needing to consume additional solid foods, any carbohydrate would suffice, though an oat flour would contain more micronutrients and fibre than other supplemental carbohydrates, and that may or may not be a meaningful factor depending on the rest of an overall diet. Of course, when possible, carbohydrates should be added to smoothies using fruit or other foods and a blender.

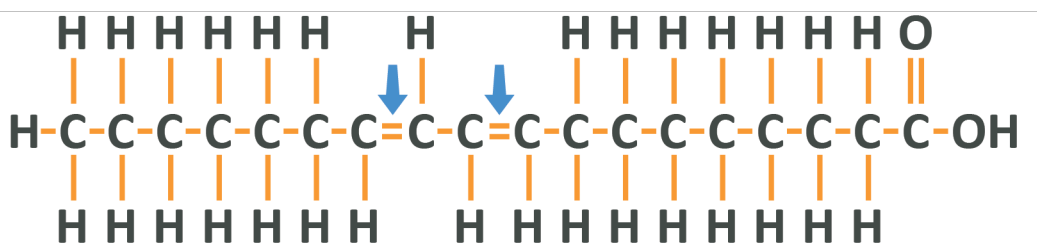
8.11. Fatty acid supplements

There are a number of different fatty acid supplements available, with some being significantly more popular than others. The full extent of the means by which these fatty acids exert their effects is far beyond the scope of this course, and so here we will simply speak in very broad terms about the real-world effects seen upon supplementing with the different products available.

8.11.1. CLA

Conjugated Linoleic Acids (CLA) are a group of 28 different isomers (molecules with the same molecular structure but different molecular shapes) of the Omega-6 polyunsaturated fat, linoleic acid. Conjugation simply denotes that one or more of the double bonds seen on the fatty acid's carbon chain are separated by a single bond between them.

Fig. 83



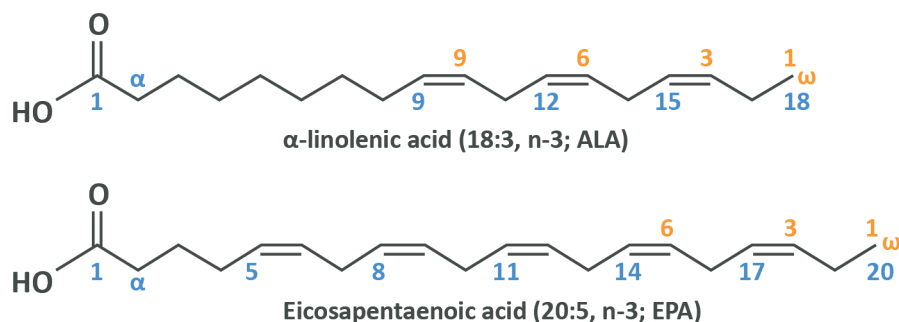
CLA supplementation is purported to impact on the action of a group of proteins known as Peroxisome Proliferator Activated Receptors (PPAR). These act as transcription factors, which are a group of proteins that bind to DNA sections to stimulate the expression of genes. PPAR's bind to free fatty acids within a cell's nucleus, travel to the DNA and then cause the expression of genes involved in fatty acid transport and oxidation, meaning that (in theory at least) the activation of this process can reduce bodyfat. Unfortunately, the evidence for this is contradictory and wholly underwhelming, meaning that although CLA can indeed activate this system, that doesn't necessarily lead to any meaningful loss of bodyfat. This is an example of a supplement which does in fact have some effect, and when that effect is extrapolated using logic, it would seem that a purchase would be justified, but when human trials are done this does not hold out. The mechanistic effect being in contradiction is something that is often seen in supplement science, and CLA was included in this module as an example of this.

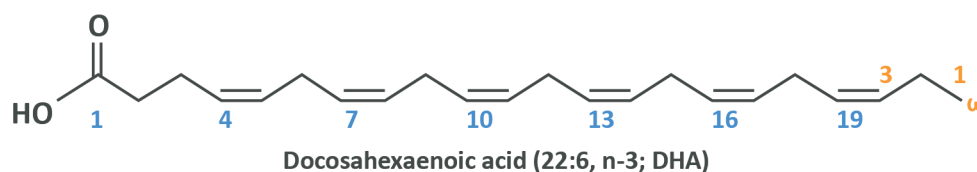
8.11.2. Omega 3 fatty acids

The Omega 3 fatty acids include Alpha Linolenic Acid (ALA – not to be confused with Alpha Lipoic Acid), Docosahexaenoic Acid (DHA) and Eicosapentaenoic Acid (EPA). The latter are found in oily fish but increasingly commonly found in supplemental form. The former is found in nuts and seeds, as well as seed oils such as flax.

ALA is an essential fatty acid meaning that it cannot be synthesised, but it is EPA and DHA which carry the most evidence of beneficial effects and ALA's main role appears to be simply as a parent molecule. ALA is converted into EPA and DHA thanks to a cascade of enzymes which both elongate it's 18 carbon chain to 20 or 22 carbons and add additional double bonds as per the below.

Fig. 84





This process is highly inefficient, resulting in only a 21% conversion of ALA to EPA and 9% to DHA in women, and even less in men. Additionally, this process shares enzymes with the process which converts the parent Omega-6 essential fatty acid linoleic acid into the various forms that it can take, and therefore a high Omega 6:Omega 3 fatty acid ratio within the diet can result in increased oxidation of ALA and decreased EPA and DHA conversion.

This unfavourable ratio is highly common due to consumption of numerous linoleic acid rich foods (such as nuts, seeds and vegetable oils including sesame and rapeseed/canola oils) and so conversion is unlikely to be high. As such, supplementation with EPA and DHA directly is the only realistic way of achieving an intake high enough to reap the benefits typically associated with Omega 3 fatty acids.

Supplementation seems to result in reduced arthritic pain, reduced post-exercise soreness and reduced symptoms of depression (specifically in those who respond well to fluoxetine, and when both are combined the effects seem to stack somewhat) as well as reduced total triglycerides in those who have elevated levels. Omega 3 fatty acids seem to reduce symptoms of systemic inflammation in women using HRT or individuals post-surgery, and increase the beneficial effects of exercise on blood lipid markers in overweight individuals.

There is also some inconsistent data to show that supplementation may result in reduced incidence of cardiovascular events without exercise, and mild evidence that it can help improve the results an obese individual will see from a hypocaloric diet. However, inconsistent data should be taken with a pinch of salt.

Overall Omega-3 supplementation appears to be beneficial in doses of 2-3g per day. Though this is unlikely to be life changing, it is one of the more robustly supported products currently available to benefit human health.

8.12. Fibre supplements

Fibre supplements are a relatively small part of the market, with each supplement having no benefit over and above that which can be gained from consuming sufficient amounts of the fibre itself within foods. In fact, foods which provide larger amounts of fibre are inherently health-promoting due to the additional nutrients that they provide and as such a fibre supplement should never be considered to be a 1-1 replacement for a typical intake of dietary fibre. With that said, soluble fibre supplementation has been shown to be effective in the management of diabetes, and psyllium husk supplementation appears effective at reducing symptoms of metabolic syndrome. These effects are likely to simply be functions of the fibres themselves and therefore a food source would have been preferable, but it's still the case that a fibre supplement could be a temporary solution for those not consuming a large amount of fibre for any amount of time, for any reason.

As you can see from the above, food supplements generally fall within a few small groups and serve a single purpose – to allow you to consume a normal amount of a nutrient to avoid the negative consequences of not doing so. These should not be considered compounds that have positive effects, but rather to be products which enable you to avoid negative ones. The next category, however, can indeed be viewed as products designed to improve some aspect of health and/or sports performance over and above that which would be expected from a given individual who had otherwise optimised their diet, lifestyle and exercise programming.

8.13. Non-food supplements

Non-food supplements fall roughly into three different subcategories. We have ergogenic aids which can augment performance in some way, either by improving your output per unit of time, or by increasing your time to exhaustion without stimulant-like properties. There are stimulants which excite your central nervous system in some manner therefore improving the same performance metrics, and then there are a heterogeneous group of ‘other’ products that don’t necessarily fit within any broad bracket.

Generally speaking, non-food supplements are things that you can typically find in foods that you may consume anyway, or things that you consume the precursors for, but which you cannot typically find in a normal diet at the doses needed for proving to be of benefit. As an example of what we mean by this consider creatine. Around 1kg of beef (weighed raw) would yield around 5g of usable creatine but this means 600-1000g of meat would need to be eaten daily just to get the 3-5g dose shown to improve sporting performance. This would be inordinately expensive (as well as being likely to result in a hugely unbalanced diet), and so supplemental creatine is considered the preferable source.

Below we will outline most prominent examples from each category. Please note that this list is not exhaustive but we have endeavoured to include as many categorically useful supplements as possible. There may be other things available on the market which can theoretically provide a benefit but these are not yet proven and so it wouldn’t be possible at the time of writing to make any claims about them. Consider it to be the case that if a supplement isn’t found below, there isn’t a great deal of robust evidence to support its efficacy. It would be prudent to follow the steps detailed at the end of this module to ascertain whether any given product should be considered.

8.13.1. Ergogenic aids

Ergogenic aids are products that enhance physical or mental performance. Here we are separating stimulants and ergogenic aids, but this is a semantic issue, as stimulants are a subgroup of the broader umbrella term.

Note: Some drugs are considered to be potent ergogenic aids, but they are beyond the scope of this course and so are not included here.

We will focus on some of the more popular supplemental ergogenic aids that could be considered useful for athletes competing in drug tested settings, or by recreational exercisers

who hope to improve their performance while avoiding products that have the potential for significant side effects.

8.13.2. Creatine

Creatine is one of the most popular sports supplements currently available, but creatine itself is not a new thing. Creatine is an essential component of skeletal muscle which was initially discovered in the early 1800's and named after the Greek word 'Kreas' meaning 'muscle'. In 1847, a researcher by the name of Leibig hypothesised that creatine was a necessary metabolite in skeletal muscle activity after he noticed that wild foxes stored 10 times more creatine in their muscle cells compared to relatively inactive captive-bred foxes. Since the 1990's a rapid increase in research has made it one of the most well-understood things we will talk about in this module.

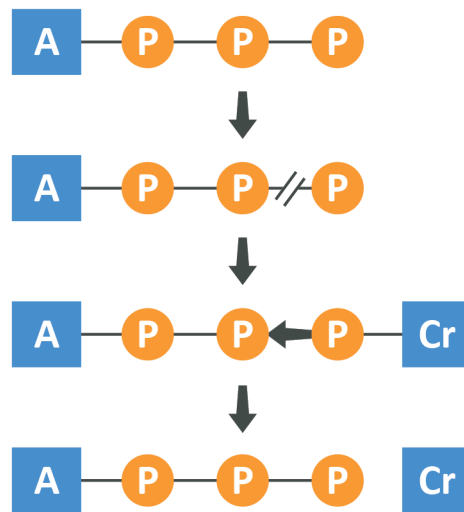
Creatine is stored primarily within muscle tissue, with around 95% of stored creatine being found here, mostly in the form 'phosphocreatine' which is simply creatine with an added phosphate group (the rest is stored as free creatine). The remaining 5% is stored mostly in the brain and testes. Although this small amount of non-muscular creatine storage may seem insignificant, it is incredibly important. A rare genetic defect carried on the X (male) chromosome causes an impairment of the creatine transporter (a specific cellular protein responsible for transporting creatine into a cell). This defect results in an almost complete absence of creatine in the brain, which seems to lead to severe speech and language delays, epilepsy and autism spectrum behaviour.

The role of creatine in exercise is in relation to the energy systems that were discussed in module 2. ATP is hydrolysed to release the energy needed to allow muscles to contract the energy needed for you to move. This ATP is quickly depleted meaning that it must be replenished via aerobic or anaerobic pathways.

These pathways are, however, not able to produce re-usable ATP for exertions lasting around 5-10 seconds. In order to keep a usable supply we need to tap in to the ATP/PhosphoCreatine system which uses molecules of creatine stored in muscle cells alongside a phosphate group as a 'phosphate donor', in the following three step fashion:

- ATP is hydrolysed to ADP to release energy
- Phosphocreatine stored in the muscles interacts with the enzyme creatine kinase, in turn losing its stored phosphate group
- ATP synthase then attaches that free phosphate to the newly made ADP, leaving usable ATP

Fig. 85



This process does not use oxygen and occurs extremely rapidly meaning that for a sub 100 metre sprint, set of heavy lifts, jump, kick, punch or other explosive work, the energy can be made available without the use of glucose or fatty acids.

The average 70kg human body contains around 120g of creatine of which 2g is turned over in the average day, meaning that it's broken down (to creatinine, which is then excreted) and then replaced. The replacement creatine can be attained via the diet in meats and fish, though the content of these foods is low, or synthesised endogenously by the fusing together of glycine, arginine and methionine. This process ensures that creatine is always available when needed, but diets low in exogenous creatine (vegetarian or vegan diets especially) tend to leave individuals with lower than average creatine stores.

Supplementation of creatine can increase the storage potential of creatine for omnivorous individuals by 10-20% and for vegetarian and vegans by up to 40%, meaning that the above process of ATP recycling using the ATP/PC energy system becomes far more efficient, leading to a number of benefits, primarily due either to improved performance ability or due to the adaptations caused by improved performance. Short-term supplementation appears to improve:

- Maximal power/strength by 5-15%, useful for most explosive endeavours
- Work capacity at maximal effort in resistance and sprint training by 5-15%, meaning that you are able to repeat a maximal performance bout for a greater number of rounds during a given session – useful for resistance training, interval training or team sports, amongst others
- Improved performance in single effort sprint training by 1-5%

This has been tested using cycling power, bench press and jump squat work capacity and sprint, soccer and swimming performance. And then longer term, supplementation seems to improve general training quality, resulting in a 5-15% increase in strength and performance.

Some physiological effects expected from creatine supplementation include increased lean body mass, strength, sprint performance, power, rate of force development and muscle size.

As mentioned, most of these effects occur not because of the direct impact of creatine itself but because creatine allows you to train longer and harder, meaning that you are able to create a greater training stimulus leading to a heightened amount of adaptation. With that said, some of the lean body mass gained from creatine supplementation is likely to occur due to water weight gain. If an individual follows a loading protocol (described below) then a gain of 1-2kg in the first 2 weeks is considered normal, with the majority of this being water.

Creatine is considered safe with no proven side effects, though it must be said that very long-term research has yet to be done and so it cannot be said conclusively that no harmful effects would come of continuous use for decades. It is unlikely, however, as short-term studies have not shown damage to the kidneys (the most logical place for harm, due to filtration) in over 5 years of use. Additionally, creatine is being explored for clinical use in the treatment/management of brain injuries, spinal cord injuries, muscular dystrophy, diabetes, blood lipid markers and pulmonary disease, leading us to consider creatine more than likely to be perfectly safe. The only notable exception to this is children and adolescents – due to the lack of concrete evidence it is unwise to recommend creatine supplementation to those under the age of 16.

Though numerous creatine isomers are available, there is no robust evidence to date to show that more expensive forms have better efficacy than the comparatively cheap form Creatine Monohydrate. Creatine monohydrate seems to be able to maximally impact muscle stores of phosphocreatine over time, and so this is the form most often recommended. Combining creatine with other supplements does not appear to improve its efficacy, with one notable exception. Combining creatine with beta alanine appears to increase the overall effect on strength, lean mass and bodyfat percentage in addition to the benefits of adding beta alanine per se. The only other thing so far shown to improve the effectiveness of creatine is carbohydrate. Adding 93g of carbohydrates, or 47g of carbohydrate and 50g of protein have both been shown to improve the muscular uptake of creatine by around 60%. This has not yet been shown to translate to improving the actual results desired (performance, body composition), but is worth considering. You could also take it alongside meals.

The dosage for creatine monohydrate is around 3-6g per day, every day. This could be taken post-workout alongside a higher carbohydrate meal or post-workout shake to take advantage of the above theoretical benefits, though this is not likely to be critical. Prior to this, a loading protocol is often used which consists of consuming 0.3g of creatine per day per kg of bodyweight for 5-7 days, split into 3-4 doses. For a 70kg individual this would equate to 4 doses of 5g every day for the first 5-7 days followed by a maintenance dose of 3-5g per day.

Note: The loading protocol isn't needed, but it is effective at increasing muscle creatine saturation levels to the highest levels to which they will go, meaning you benefit from supplementation much more quickly.

8.13.3. Beta alanine

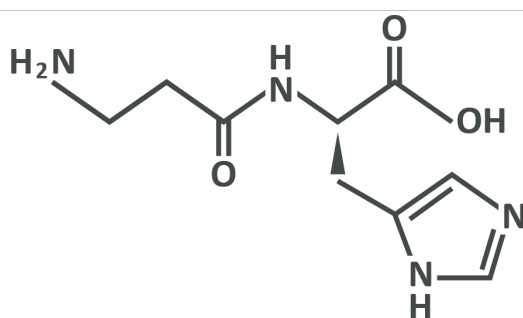
Much like creatine, beta alanine is a naturally occurring metabolite found in muscle tissue. It's a non-proteogenic amino acid (unlike the 20 noted already it cannot be incorporated into proteins because it is not coded for by any genes) that is either produced in the liver, endogenously, or consumed in the diet via poultry or meat.

Its key role is as the 'rate limiting' factor in carnosine production. Carnosine is a dipeptide used in a multitude of physiological functions, made by combining beta alanine and L-histidine via the action of carnosine synthase enzymes. Beta alanine is the rate limiting factor because serum levels of BA are always lower than levels of L-histidine, and so supplementation of BA leads to an increase of stored carnosine. The enzyme carnosinase which is responsible for breaking down carnosine to its constituent parts is expressed in the blood and some tissues but not skeletal muscle – meaning that while beta alanine supplementation increases carnosine levels in the muscle (where it is synthesised), oral supplementation of carnosine directly leads only to an increase of carnosine catabolism in the blood.

Supplementation with beta alanine, in fact, leads to an increase in skeletal muscle carnosine of up to 80% after 10 weeks. So, what's the fuss about carnosine?

Reflect back on the process of anaerobic respiration – glucose undergoes glycolysis resulting in the production of 2 pyruvates and free H^+ ions. Those ions would ordinarily be 'picked up' by NAD^+ and carried to the electron transport chain but as oxygen is not available that isn't possible. As H^+ ions build-up during anaerobic activity, they lower the cell's pH, making it acidic. This is what causes 'the burn' and leads to a rapid onset of fatigue which ultimately ends a bout of intense exertion.

Fig. 86



Where carnosine comes in is at this point. Carnosine has what is known as an imidazole ring that contains 3 carbons, 2 nitrogens and 4 hydrogens, and which is capable of picking up those stray H^+ ions to render them inert. This helps to buffer intracellular pH and hold off fatigue. When studied, supplemental Beta Alanine leads to a reduction in exercise induced acidosis. This is the primary reason carnosine is important but this is not the only role it plays. Carnosine can also neutralise free radicals (reactive oxygen species/ROS) and prevent their production by interacting with some of the intermediary metals (iron and copper) responsible for some amount of the ROS produced during exercise.

In short, beta alanine increases muscle carnosine levels, and that carnosine helps performance in physical activities lasting around 60-240 seconds, but not in those lasting under 60 seconds as acidosis is not likely to be the primary cause of exhaustion here.

All of this translates to a few notable performance improvements including:

- Improved time to exhaustion in cycling trials by around 13-14%
- Improved time to exhaustion in running by around 8-15%
- Improved performance in trials taken to voluntary exhaustion (perhaps a more important metric, as this is more likely to be important in free-living situations)
- Greater improvements in time to exhaustion post 6 weeks of interval training using a beta alanine supplements
- Improved 2000m row time
- Delayed neuromuscular fatigue in sprint cycling
- Improved markers of fatigue and therefore greater volume performed in very high volume resistance training. This is most likely to reflect well on crossfit or similar endeavours, as again acidosis isn't often the key limiting factor in standard resistance training. As noted above, however, combining BA with creatine may improve the total effect of both in terms of strength accrument

There are no known long-term side effects of beta alanine supplementation. It is also worth noting that beta alanine has some antioxidant properties meaning that it could be beneficial for general health and disease prevention assisting with improving exercise capacity and performance. The only thing that should be discussed is the short-term unpleasant side effect caused by supplementation known as paraesthesia. This is a tingling of the skin caused by interactions with histamine receptors (usually activated to make you itch if allergic to something or similar). This is harmless and temporary but possibly unpleasant – it can be mediated by breaking a daily dose into 2-3 doses per day or it can be taken with food.

The ideal dose is 4-6g per day, for at least 2-4 weeks. The threshold dose seems to be around 179 total grams for maximising saturation, meaning that it would take around 4 weeks at 6 grams or 6 weeks at 4. After this, the maintenance dose appears to be the same, 4-6g per day.

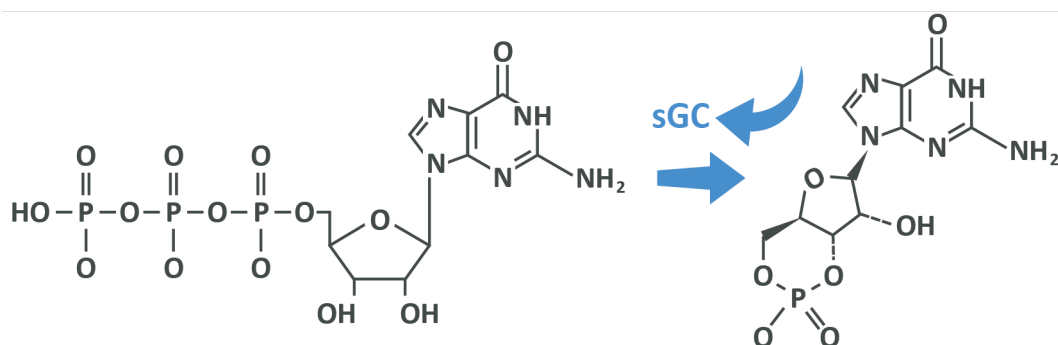
8.13.4. Citrulline malate

Citrulline Malate is a combination of the amino acid citrulline with malate. This supplement has a somewhat complex mechanism of action.

Within many of your endothelial cells, including those of the vascular system, is a molecule called guanosine Triphosphate. This is 1 guanosine with 3 phosphates, and it can behave in a similar manner as ATP – with hydrolysis removing one of its phosphate bonds to release energy. A key role of GTP, however, is to be converted into cyclic Guanosine Monophosphate (cGMP) which is simply a guanosine with one phosphate group that has become cyclical

(linked into a circle). This occurs due to the action of an enzyme called Guanylate Cyclase as you see below:

Fig. 87



cGMP is the first step in a cascade resulting in vasodilation, a widening of blood vessels.

Guanylate cyclase is not active under normal circumstances, however. It's activated by Nitric Oxide (NO) – a small soluble molecule able to diffuse across the cell walls on the interior wall of blood vessels and enter the cytoplasm. Nitric oxide is produced via the action of nitric oxide synthase (NOS) using the amino acid arginine. This means that serum levels of arginine are rate limiting for nitric oxide production, and so an increase in arginine concentration in the blood leads to an increase of nitric oxide, then guanylate cyclase, and in turn GMP.

GMP is then used to stimulate another enzyme called protein kinase G (PKG). Kinases add phosphate groups to proteins, and so PKG is then free to alter and 'activate' a number of other intracellular proteins, resulting in vasodilation.

That vasodilation leads to improved blood flow, meaning a greater delivery of nutrients and oxygen to muscle tissue, and an increased rate of removal for some of the waste products that result in fatigue such as ammonia. Increased vasodilation can therefore improve endurance alongside muscle pumps (which may be beneficial to hypertrophy to a small degree, owing to cellular swelling).

Where citrulline malate comes into this, is in the fact that citrulline supplementation increases plasma arginine levels very effectively (citrulline is converted to arginine via the kidneys once in the blood) but oral supplementation of arginine does not, meaning it does not increase plasma NO.

To recap – supplementary citrulline malate leads to increased plasma arginine, which results in increased nitric oxide via the enzyme nitric oxide synthase, which crosses the cell membranes of cells in blood vessels and activates guanylate cyclase, thus converting GTP to cGMP and activating a cascade of reactions that result in vasodilation.

To add to that, the malate from citrulline malate, when separated from citrulline, can influence the amount of ATP that can be produced during exercise, by 34% in a study by Bendahan in 2002.

When translated to human trials, chronic citrulline malate supplementation appears to reduce perceived fatigue, increase time to exhaustion, increase potential training volume completed, reduce muscle soreness and improve performance of exercise completed on consecutive days. Of note is that many medications for angina or similar conditions use this pathway to help ease blood flow, and so an NO based supplement may be beneficial for those with poor blood flow, and it can be effective at relieving some amount of physiologically grounded erectile dysfunction.

Despite being shown to improve work capacity, there is no evidence as yet to suggest that Citrulline Malate can improve power output.

To take for erectile dysfunction, take 1000mg 3 times per day with meals. For sporting performance a dose of 6000-8000mg must be taken shortly prior to a workout.

8.13.5. Nitrates

Other products exist which utilise the above pathway, with nitrate supplements (typically in the form of beetroot) being the most prominent. Nitrate supplementation is able to increase serum nitrite levels, and this can in turn increase nitric oxide levels. Nitrate supplementation (from beetroot) has been shown to improve performance in running, cycling and swimming, and nitrate supplementation in an isolated form has been shown to improve crossfit performance, making it something worth considering for continuous-effort based activities.

8.13.6. Stimulants

There are a number of different legal stimulants which could be taken either for the improvements in cognitive function and focus, or perceived energy (as well as the performance benefits associated with that) and for these purposes there are no legal products which can match up to caffeine. Ginseng is one commonly recommended alternative but no good evidence exists for it improving energy (certainly in the same way as caffeine does) and guarana is simply a source of caffeine much like chocolate or coffee beans.

8.13.7. Caffeine

Caffeine has a number of different pathways for action, but the main way in which it can wake you up lies in the fact that it blocks adenosine receptors in the brain, effectively disrupting the homeostatic regulation of sleep pressure (check back to the sleep module for more details on this).

The binding of caffeine to adenosine receptors also causes the secretion of the neurotransmitter acetylcholine, responsible for stimulating areas of the autonomic nervous system to increase heart rate and blood pressure, and other neurotransmitters involved with increasing arousal – this all makes you more able to remain alert physically as well as mentally. In addition, it disrupts the secretion of the ‘relaxing’ neurotransmitter known as Gamma-Aminobutyric Acid (GABA) which ordinarily inhibits various alerting neural pathways, thus leading to drowsiness, and finally it can cause secretion of dopamine to make you feel good. The net result of this is that fatigue is blunted while alertness is promoted, you feel more positive and you are more physically prepared for performance.

In doses ranging from as little as 32mg to as much as 600mg (for reference, a Red Bull contains 82mg), caffeine has been shown to augment cognitive performance by improving alertness, reducing reaction time and having a small impact on short-term memory. It can also improve mood at doses of 250mg.

Where caffeine really shines is in terms of exercise performance. Caffeine in doses of 3-6mg per kg of bodyweight can improve performance in exercise lasting up to 2 hours, meaning that this is not specific to any particular energy pathway, and it does so through a variety of ways including power output, rate of perceived exertion (how hard exercise feels at a given intensity is reduced), strength endurance and speed to a significant degree. There is no impact on maximal effort single repetitions, however. This effect is not mediated by habitual consumption, meaning that pre-workout caffeine intake is effective even in those who typically use caffeine in regular life. Of note is that supplemental pre-workout caffeine from caffeine anhydrous (an isolated form used in supplements) appears more effective than coffee and is easier to dose accurately.

A final reason cited for caffeine consumption is as an aid to fat loss, with caffeine being a key ingredient in many thermogenics. Research indicates that caffeine can increase metabolic rate by 3-11% in some trials, and in fact long-term research indicates that habitual caffeine intake is correlated with decreased bodyweight. This could be in relation to caffeine's thermogenic properties or to its ability to help reduce appetite as indicated by the fact that supplementation generally reduces subsequent calorie intake when researched. A warning here, however, is that the appetite blunting effect of caffeine does not appear strong in habitual users meaning that those using caffeine all of the time may not get the benefits that others would. Of course, due to caffeine's impact on performance and fatigue resistance, it can be hypothesised on top of the above that caffeine intake before training during periods of caloric restriction may undo the performance detriments associated with low energy intakes, and therefore it may improve calorie output via this means. Finally, animal data indicates that NEAT may be increased by caffeine though this has not been shown in humans as yet.

8.13.8. Yohimbine HCL

Yohimbine (as Hydrochloride for the isolated version, or Pausinystalia bark extract for the plant extract) is a powerful stimulant which instigates release of various chemicals including the catecholamines, adrenaline and noradrenaline. These are responsible for instigating the 'fight or flight' response meaning an increase in levels of usable energy in the blood (from glucose and fatty acids), increased heart rate and elevated blood pressure. Catecholamines are therefore able to mobilise fatty acids from fat cells in order for them to be oxidised.

This is not typically something worth a great deal of consideration. Fatty acids can be mobilised simply by creating a calorie deficit and if a deficit is not in place, mobilisation doesn't improve fat loss (fatty acids which have been mobilised simply return to adipose tissue). With that said, there is more to the picture.

Fat cells have 2 different receptors relevant to this discussion, alpha-2 and beta-2 receptors. Beta receptors are the targets for various chemicals (including the afore-mentioned

adrenaline), bound in order to initiate lipolysis, but the alpha receptors are considered an inhibitory system which inhibits this process. Yohimbine not only activates Beta-2 receptors via catecholamine release, it antagonises (blocks) the Alpha-2 receptors and prevents this inhibitory mechanism from taking hold. This becomes important for extremely lean individuals who have areas of fatty tissue richer in alpha receptors – often dubbed ‘stubborn fat’, as it can facilitate increased fat loss – but it is unlikely to make a significant difference in normal weight or overweight individuals looking to become leaner. Critically, yohimbine must be taken in the fasted state to have these effects, as insulin mediates B2 receptor antagonism.

On top of this, yohimbine may have the ability to blunt appetite though this is only shown in rats at present.

The recommended dosage is usually 0.2mg per kg of lean body mass, often combined with caffeine at a dosage of around 2mg per kilogram. These together have a synergistic effect of prolonging catecholamine release, and so may create a more profound effect when taken together.

When considering any stimulant, it would be prudent to consider any side effects. These include heightened blood pressure, anxiety, increased heart rate, sleeplessness and all of the immunosuppressing effects of continual catecholamine release. These will impact individuals differently, with lifestyle factors like smoking, age, sex, weight and individual genetic variants altering the magnitude of side effects and even the half life of whichever you take. For stimulant use start conservatively and only increase dosage if you perceive a need – and of course it must be said that perpetual stimulant use may simply be masking poor sleep, and that is not recommended long-term.

Seeing as yohimbine is similar to caffeine in its stimulatory effects, dosage and overuse is a prudent consideration. There might be evidence to suggest that yohimbine HCL could have a positive effect in very lean individuals training in a fasted state for increased fat loss in stubborn areas, otherwise it is a supplement outside the remit of most fat loss scenarios.

8.14. Other products

8.14.1. Arachidonic acid

Arachidonic Acid (AA) is an Omega-6 polyunsaturated fatty acid with 4 double bonds. It's a primary constituent of cell membranes, comprising 10-20% of the fatty acids in the membrane of cells in skeletal muscle. It's a non-essential fatty acid meaning that we are able to synthesise it (unlike obligate carnivores like cats who cannot), being the final product of the Omega-6 fatty acid synthesis process starting with lipoic acid (the Omega 6 essential fatty acid).

AA increases Muscle Protein Synthesis (MPS). It does this by being converted to a prostaglandin (a lipid which has a hormone-like effect) called PGF2 Alpha during exercise. PGF2A is then able to activate MPS via the same mechanisms as leucine does. It's been shown in one study to increase muscle mass and performance on a Wingate test at a dose of 1,500mg per day over 8 weeks, though at the time of writing this study had not been replicated.

AA does not appear to increase any markers of poor health upon supplementation and can be considered safe. The evidence for its efficacy is currently very thin, but this could be something you consider experimenting with if you are happy to divert spare money towards this avenue.

8.14.2. Probiotics

Probiotics are live bacterial strains administered orally in an effort to alter the bacterial flora of the host towards a more positive balance. We have already discussed in the Fibre module the impact that a healthy gut flora can have on a number of different physiological markers and because of this and some preliminary trials, probiotics are theorised to have the following effects:

- Improved intestinal health
- Enhanced immune response
- Improved blood lipid profile
- Acute diarrhoea alleviation
- Alleviation of GI problems experienced post treatment with antibiotics
- Reduction in pathogenic bacteria thanks to competing for resources

In addition to the above it has been proposed that (because there is a big difference between the gut flora of bottle fed and breastfed children, and between the incidence of allergies in those same populations) probiotics may help with the avoidance of allergy development, but there is no evidence for this. There is also no evidence that allergies (specifically asthma) are helped by probiotic use once they have developed.

These benefits are exerted via short-chain fatty acid production, stimulation of mucosal barrier function (they help the cells lining the colon perform their role), immunomodulation and lowering of the gut pH (making it more acidic).

Useful bacterial genera include *Lactococcus* and *Bifidobacterium* which are both tolerant to acid and bile, making them ideal for oral application. They adhere to mucosal and epithelial surfaces meaning that they can stay in the GI tract and exert effects on these tissues, they are antimicrobial against pathogenic bacteria and they help hydrolyse bile salts. Some specific strains of these and other genera which could prove be useful are shown in the table below:

Fig. 88

Lactobacillus species	Bifidobacterium species	Other lactic acid producing bacteria	Non-lactic acid producing bacteria
<i>L-acidophilus</i>	<i>B-adolescentis</i>	<i>E-faecium</i>	<i>Escherichia coli</i> strain nissle
<i>L-casei</i>	<i>B-animalis</i>		<i>Propionibacterium</i> <i>freudenreichii</i>

<i>L-crispatus</i>	<i>B-bifidum</i>	<i>Saccharomyces cerevisiae</i>
<i>L-gasseri</i>	<i>B-breve</i>	<i>S-boulardii</i>
<i>L-johnsonii</i>	<i>B-infantis</i>	
<i>L-paracesei</i>	<i>B-longum</i>	
<i>L-plantarum</i>		
<i>L-reuteri</i>		
<i>L-rhamnosus</i>		

As you can see, the list is long and complex, and of course each beneficial effect is associated to a different strain, which would be impractical to lay out here. Suffice to say that at present the only benefits of probiotic use with anything approaching robust evidence are:

- *L-rhamnosus*, *L-casei* and *S-boulardii* use can help against post antibiotic diarrhoea when used immediately after the antibiotic course
- *L-reuteri*, *L-rhamnosus*, *L-casei* and *S-boulardii* can help reduce acute diarrhoea in children
- *L-reuteri*, *L-rhamnosus* and *L-casei* can help fight rotavirus
- *L-rhamnosus*, *S-boulardii*, *L-acidophilus* and *B-bifidum* may help travellers' diarrhoea
- *S-thermophilus* and *L-delbrueckii* subspecies *Bulgaricus* may be able to alleviate the symptoms of lactose intolerance by exerting enzymatic effects on the lactose. This is inconsistently shown, however, and so individuals should assess carefully whether they wish to experiment

As you can see the evidence for probiotic use is interesting but the study of these products is relatively new, and of course the correct strain (at the correct dosage, usually around 100,000,000 to 1,000,000,000 bacteria per day) must be used for any specific purpose. If you are considering probiotic use, we advise you pay very close attention to what you are taking and why, and consider alternative approaches first with probiotics being an addition. Most individuals will never need to use a probiotic.

8.15. Nootropics

Nootropics are a broad group of supplements taken to create some measurable effect on brain function, primarily cognition, alertness, focus/concentration, mood and memory, in healthy individuals (as opposed to, for example, SSRI's used by those with depression).

There are a huge range of different products used and the full extent of these is beyond the scope of this course. We will briefly cover the important subgroups below, and encourage you to heavily research anything you are considering taking for this purpose as, broadly speaking, human research is exceedingly thin.

8.15.1. Racetams

Racetams (RA-seh-tams) including piracetam and others are drugs used to alter brain function. They impact numerous neural synapses including those with GABA, Glutamate and cholinergic receptors and are promoted to improve cognition, creativity and focus. As yet there is very little evidence that they do any of this in individuals who don't have cognitive impairments.

8.15.2. Stimulants

Many stimulants can have some amount of impact on cognitive function in therapeutic doses. These include:

- **Methylphenidate (Ritalin):** This improves concentration, planning, reaction time and focus, especially in those with ADHD but also in the general population
- **Eugeroics (Modafinil):** This is often prescribed for those with sleep disorders as it can improve numerous cognitive markers in those with sleep deprivation, but in healthy volunteers it has also been shown to improve reaction time, logical reasoning and problem solving
- **Amphetamines:** These can increase alertness, and at low doses can improve memory consolidation
- **Caffeine:** This has already been discussed above, but needless to say it can increase your ability to complete mental tasks
- **Nicotine:** Nicotine (from smoking or other sources) can improve fine motor skills, orienting attention and working memory

Needless to say, most of these products can have side effects and many stimulants are potentially addictive. To reiterate, always thoroughly research any product you are considering, potentially speaking to your GP before initiating use.

8.16. Testosterone boosters

The final supplement category we will consider here are testosterone boosters – herbal products promoted to increase testosterone levels and in doing so improve wellbeing, sexual potency and body composition.

Much like Nootropics this is a huge category with numerous different available products, but the overall message is that non-drug testosterone boosting supplements may increase your total, free or bound testosterone (around 95-99% of testosterone in your blood is bound to proteins to render it inert) by less than 10%. Even the lowest dose of injectable steroids typically used will increase testosterone by over 200-300%, and therefore it should be self-evident that testosterone boosters are unlikely to increase muscle mass or meaningfully reduce bodyfat levels (two effects of supraphysiological testosterone levels).

With that said, maca, tribulus terrestris and fenugreek supplementation can increase feelings of wellbeing and libido, which are two things often sought from testosterone boosters, and so these could be considered, even though they do not actually affect hormone levels.

8.17. Who is most likely to benefit from supplementation?

Supplementation should be used in a targeted manner, with specific products used for specific reasons. As such, it's useful to reflect on some populations that are more likely to benefit from supplementation than others. Of course, this list could never be comprehensive as there are more situations that warrant supplementation than could fully be elucidated. It should be taken as given that specific individuals within the populations below do not necessarily need supplementation as this would depend very much on some aspects of the specific applications of an approach and in essence, the actual foods that any individual eats.

8.17.1. Vegans/vegetarians

As you learned in module 3, there are a number of different micronutrients present in animal derived foods which are either partially lacking, in a poorly absorbed form or completely absent from plant based foods. Examples of this include iron, vitamin A, calcium and some B vitamins, especially B12.

Deficiencies (or insufficiencies) in these key nutrients could be problematic, and due to the dietary choices made by vegetarians and vegans they are more likely to experience these issues than the general population would be. Food supplements (either individual nutrients or a broad spectrum multivitamin) would possibly be worth consideration here if large amounts of plant-based sources are not included in the diet. Furthermore, vegans and vegetarians are unlikely to consume enough EPA or DHA for optimal health and due to the low conversion rate of ALA to these, vegans or vegetarians may wish to supplement with an algae based product. Finally, though the amount of protein which can be consumed by vegans is more than adequate in most cases, those on restricted calorie intakes or those with especially high needs may find that protein supplementation could be of use.

8.17.2. Those on a budget

While it could be argued that this is less than ideal, there is a strong case that protein powders and EPA/DHA supplements offer an affordable alternative to regular consumption of oily fish for EPA/DHA and large amounts of highly priced animal produce for those with an elevated protein need. By swapping daily EPA/DHA supplementation and 1 serving of a protein powder for these more expensive foods, an individual can still expect to meet their macro and micronutrient needs, but should notice a marked reduction in their food bill. This, of course, also applies to those who simply don't enjoy eating fish or large amounts of other protein-containing foods.

8.17.3. Those following a restrictive diet

As we mentioned in module 3, a restrictive diet is one which is not balanced, though this may not mean that someone is lazy or uneducated. Those who are intolerant to dairy are missing an important food group, as are coeliacs and those who choose to adopt a ketogenic approach. In addition to these demographics, people who have a very low overall food intake for the purpose of losing fat. For example, while a 90kg individual will have no problem consuming enough micronutrient dense foods while losing fat, a 55kg individual may not, and therefore supplementation could be warranted.

If you have restrictions on your diet for any reason, it's important to make sure that those restrictions will not reduce your ability to achieve nutritional sufficiency and if they do supplementation could be a solution. Of course, the specific nutrients required would depend on the imbalance at hand, and this must therefore be taken on a case by case basis.

8.17.4. Those with a very high activity level

An individual with an extremely high activity level will necessarily need to consume a lot more calories than someone with a typical lifestyle and after a certain point consuming whole foods becomes problematic. If an individual is struggling to consume whole foods to the calorie level that they need, then supplementation with carbohydrate or protein powders, potentially blended into high calorie shakes can be an answer. Additionally, there is some evidence that minerals such as magnesium, zinc and iron are common deficiencies amongst athletes and so these supplements may warrant looking at (though testing for deficiency is worthwhile before making assumptions here).

8.17.5. Those looking for maximal athletic performance

Once an individual has found a training regimen congruent to their goals and has achieved a dietary approach which is in support of that (alongside sleep and stress management), supplementation can be a useful tactic for squeezing out the last few percentage points for performance. The specific supplements used will of course vary from sport to sport and individual to individual, and so we recommend looking at the ergogenic aids section of this module to make informed decisions regarding supplementation.

8.17.6. Those who live outside of the tropics

As you learned in module 3, for those living outside of a narrow band around the equator, sun exposure for at least some of the year is less than is needed to synthesise adequate vitamin D. Supplementation of 400iu of vitamin D3 during winter months is now recommended by the UK Government and there is some evidence that taking more may be of merit, so long as you are cognisant of the 10,000iu TUL mentioned in Module 3.

8.17.7. Those who have taken a course of antibiotics

Antibiotics are a fantastic medical tool. They can kill harmful pathogens and return you to health, rendering previously fatal illnesses little more than a few days off work and an inconvenience. Unfortunately, they are not without side effects, including reduction and the imbalancing of your digestive bacterial population (cases of sickness and diarrhoea can do the same). Post antibiotic probiotic use may have efficacy for reducing or eliminating these issues.

8.17.8. Those with certain pathologies

There are certain conditions such as chrons or ulcerative colitis, as well as gall bladder removals and bowel surgery which can hamper your ability to absorb nutrients. If you or someone you are advising has a digestive or bowel related condition, speaking to a doctor is a very good idea as supplementation may be required.

8.17.9. Peri-menopausal women

Post-menopausal women (and for men in their 60's) can find that bone loss can be a problem, so calcium and Vitamin D supplementation could be a very valuable addition if your diet or lifestyle do not provide it. Additionally, there is some evidence that supplementation with zinc and magnesium may ease menopausal symptoms.

8.17.10. Pre-and post-natal women

Around pregnancy and lactation women are encouraged to supplement with folic acid and vitamin D3. No other supplements are recommended for routine use, though fish oils may promote healthy development and protein powders are considered safe in the context of a balanced diet.

8.18. How do you know whether or not you should use something?

The thought process which governs the decision around whether to use a supplement or not is somewhat different for food supplements and non-food supplements. The only reason you would use a food supplement is if you cannot consume sufficient amounts of a given nutrient on a regular basis – for example you may have a dietary imbalance for any particular reason. You might also have higher than usual requirements for a number of reasons. If this is the case you should assess your likelihood of deficiency (or speak to your GP for a blood test) and then supplement accordingly. As mentioned before in this course, always be wary with supplementation of nutrients like copper or retinoids which can become toxic with overconsumption. A broad-spectrum multivitamin would be another option here, provided it ensures adequate intake of the nutrients you are concerned about most.

If you're looking to supplement with a non-food supplement, your thought process should generally follow this path:

- First ask yourself if your overall dietary approach and lifestyle is in line to a reasonably high degree. This does not necessitate perfect eating and sleeping habits, but if these factors are not either 80-90% in place or on their way to being in place through progressive alterations to your lifestyle, then this should be your point of focus before considering supplementation. Sleeping well when you don't currently will improve your sporting performance more than creatine in the same situation, as well as conveying other benefits
- Can you afford to buy it? If you can't, work with other factors to rectify imbalances, and know that you can achieve excellence without ergogenic aids
- Is the supplement going to benefit you for your specific goals? There are multiple supplements which are beneficial but only for those who need them – a power athlete supplementing with nitrates, and a person eating a lot of vegetables but supplementing with vitamin C are both wasting money
- Is the supplement supported by the current body of evidence, reliably? Each product listed above carries a strong body of evidence unless otherwise stated. We have not mentioned some supplements which could be taken to some effect, of course, but

most useful products are listed here. Whatever you do choose to use it's critical that you learn if and how it works. Never forget that extraordinary claims require extraordinary evidence and that goes double for supplements you're going to pay money for and then consume. For impartial advice on supplements we recommend looking at the free resources on www.examine.com

- Do you know the dosage, required timing and specific forms you need? Opting for suboptimal forms of a supplement or incorrect dosages may be counterproductive
- Do you have realistic expectations of the effect and the timeframe in which you will feel these? Supplementation with vitamin D or whey protein is unlikely to make night-and-day, subjectively noticeable differences but they can both be very helpful, whereas beta alanine may create paraesthesia even if you don't benefit from its use due to your sport. Be clear on what you expect to happen

After running through the above thought process, add a supplement one at a time to assess its efficacy. If you add 2 or 3 supplements at once and your sporting performance improves you can't tell what it is that created the effect, and so it's a good idea to go one by one and pay close attention to the effects. Of course, adding fish oil and a multivitamin or other supplements which don't have effects you can immediately feel need not be done in this way.

8.19. Supplemental ethics

As we hope you appreciate, there are a large number of supplements available to consumers and not all of them will be as effective as potentially claimed. Not only that, but the supplements that are effective may not be something that everyone should look to use because the application of supplements should be specific. As such, when talking about supplements to others, it's critical that the full picture is communicated – those who work with others in a coaching capacity need to bear this in mind above all. If you are a coach, or indeed if you are working with a coach, bear in mind that it is unethical in most cases to sell supplements to clients.

This may not always be the case – if a coach or gym has supplements available, as well as unbiased and fair information on them so that clients/customers can buy from a reputable source then this is perfectly permissible, but it is not ethical to push or strongly promote supplements to those who may view you as an authority figure – especially when you personally profit from doing so. As a general rule, each individual should be free to make up their own mind about what to buy, using impartial information available – if you think that someone you know may benefit from a supplement, refer them to [examine.com](http://www.examine.com) above so that they can read up on it for themselves and decide whether or not they feel that a supplement is right for them.

In the next module, we will start to look in depth at you, the person who is applying all of this. While we like to think we make all of our food choices consciously, that may not be the case, so rather than your unconscious mind and surroundings working against you, it's time to make them work for you.

8.20. References

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