# Supplements

The use of dietary supplements is widespread in the general population and even higher among athletes and exercisers. The ability to evaluate the validity, safety and quality of dietary supplements marketed for weight loss, muscle gain or improved athletic performance adds credibility and value to Nutrition Coaches. Given the multi-billion-dollar supplement industry, myriad products, advertisements and claims to help exercisers and athletes attain the desired results from their use, as well as an apparent lack of understanding of how supplements are regulated, there is a need for guidance grounded in science and an understanding of the marketplace.

**Prevalence of use**

The prevalence of dietary supplement use in North America is widespread, with approximately half of the general population reporting taking at least one dietary supplement, with the most commonly used supplement being a multivitamin and mineral formula (Blumberg et al., 2017). Among older adults, dietary supplement use is higher, with 63% of people over age 51 and 75% of individuals over age 71 reporting using at least one dietary supplement (Cowan et al., 2018). The majority of health club members (84%) report taking a range of products, from multivitamins to protein powders, and among adults in the United States who reported making a serious attempt at weight loss, over 1/3 have used a dietary supplement for that reason (Dickinson, Blatman, El-Dash & Franco, 2014; Morrison, Gizis & Shorter, 2004; Pillitteri et al., 2008).

A systematic review of 159 studies revealed that athletes use dietary supplements to an even greater extent, with the highest prevalence among elite athletes compared to non-elite athletes (Knapik et al., 2016). Undoubtedly, Nutrition Coaches will be asked for guidance on which, if any, dietary supplements can help support health, weight loss, muscle gain and athletic goals. Thus, having the knowledge to provide guidelines based on the body and strength of evidence related to supplements is of high value to clients, regardless of their participation in competitive sports.

It is also important to take into consideration the hierarchy of nutritional strategies for accomplishing the desired outcomes. The following model provides a contextual overview of the impact each level has on an individual’s nutritional status. Similar to Maslow’s Hierarchy of Needs (which is concerned with life as a whole), foundational nutrition strategies need to be met before giving concern to the next level.

Just like how physiological and safety needs must be met before one can focus on psychological and self-fulfillment needs in Maslow’s model (Figure: Maslow’s Hierarchy of Needs), daily energy requirements for health need to be met before undertaking more specific dietary strategies and supplementation. This can serve as a model for prioritising daily, weekly and overall dietary choices, actions and goals (1 = highest/foundational priority).

5 - Proper supplementation to support body composition, training and performance

4 - Meeting micro-nutrient needs based on nutritional gaps in the diet

3 - Tailoring carbohydrate and fat amounts and timing based on client preferences and energy needs for training and competition

2 - Meeting daily protein requirements for the desired outcomes

1 - Daily energy needs according to the client’s goal and the demands of the activity

A pyramid of maslows with text

AI-generated content may be incorrect.

This model implies that daily energy needs, protein intake and essential nutrient requirements are of higher priority than supplements, including ergogenic aids because they have a greater impact on the individual’s body composition or performance goals compared to supplements. However, this is not to dismiss the benefits certain dietary supplements may have on health and the desired aesthetic or performance outcomes when properly selected, utilised and added to a solid nutritional foundation. Understanding the regulatory framework around dietary supplements, the related body of research on any particular ingredient of interest, and the various independent agencies that test the quality of supplements is critical for Nutrition Coaches to be able to make sound recommendations to the general population and athletes alike.

Coach's Corner

By providing an evidence-based approach to dietary supplements, including criteria for the proper selection of products, Nutrition Coaches can prevent wasteful spending, adverse health effects, inadvertent doping and subsequent suspensions from athletic competition, all while gaining the benefits certain dietary supplements have to support fitness, exercise and athletic performance goals.

Critical!

For fitness professionals working in Australia, it is essential to follow the AusREPs Scope of Practice along with the Nutrition Coach Scope of Practice outlined here in this course. Additionally, working as a Nutrition Coach in Australia requires adherence to the Australian Nutrition Guidelines in addition to the recommendations outlined in this course for the USA and the UK.

Click the following links to learn more:

[Scope of Practice for AusREP](https://fitness.org.au/articles/policies-guidelines/scope-of-practice-for-ausreps/4/38/20)

[Australian Nutrition Guidelines](https://fitness.org.au/articles/policies-guidelines/nutrition-advice-within-scope-of-practice-for-ausreps/4/1356/20)

However, no matter where in the world Nutrition Coaches are working, the important thing to remember is that their job is to educate and empower clients to make their own nutritional decisions, not prescribe specific nutrition plans for them.

The current laws governing dietary supplements should be taken into consideration for proper selection and utilisation for the general population as well as by athletes, regardless of their competitive level or professional status. In the United States, the regulation of supplements is dictated by the Dietary Supplement and Health and Education Act (DSHEA) of 1994 (U.S. Food and Drug Administration, 2018). Under the provision of the DSHEA, dietary supplements, which include herbs, botanicals, vitamins, minerals and other ingredients, are regulated as food products. In contrast, over-the-counter medication and prescription drugs are subject to premarket testing and approval by the U.S. Food and Drug Administration (FDA).

Manufacturers of dietary supplements are responsible for adopting current good manufacturing practices (cGMPs), which are standards and guidelines to ensure supplements are made properly. Manufacturers are also obligated to make accurate label claims and are prohibited from marketing supplements to prevent, treat, cure or diagnose a disease. Similar to product safety and efficacy, label claims for supplements do not have to be approved by the Federal Trade Commission (FTC) or the FDA prior to their sale and marketing. Hence, the proper testing of raw materials, manufacturing of ingredients and verification procedures for the identity, composition and purity of finished products are all the responsibility of the individual supplement producers.

To enforce these supplement manufacturing rules, as opposed to requiring testing and approval of every dietary supplement prior to sale, the FDA performs annual inspections of randomly selected manufacturing sites to assess compliance with cGMPs. In the 2016 FDA Inspection Report of nearly 500 manufacturing facilities, infractions were found at nearly 2/3 of the facilities (ConsumerLab, 2017). An average of six infractions were discovered at each facility, with the most common infractions involving the lack of processes for verifying the identity of raw ingredients and assessing the purity, identity and composition of finished products. This lack of compliance with the cGMPs by supplement manufacturers results in poor product quality, including ineffective formulas and contamination with hidden ingredients.

The FDA has the power to recall a product and does so after serious or sufficient adverse events are reported or new, unapproved ingredients are discovered. The FDA maintains an online database of over 900 supplements that have been found to be contaminated with prescription drugs and illegal substances (U.S. Food and Drug Administration, 2018). Contaminated supplements have been purported to be the cause of negative health effects in the general population and positive drug tests among athletes, resulting in their suspension from competition. However, there appears to be a general lack of awareness of the buyer-beware supplement market as a result of the DSHEA. Fortunately, there are methods and tools in place to ensure standards are being adhered to.

## Guidelines for supplement selection

An evidence-based approach to dietary supplements includes: evaluating whether a supplement is safe and effective based on the strength of the research and the population studied; the potency of the formula, including the dosages and ingredient forms; whether the ingredients are legal, and whether the finished product has undergone independent testing for the accuracy of label claims and the absence of contaminants and banned substances.

**Strength of the research**

The strength of the evidence on dietary supplements varies greatly and the body of research on safety and efficacy should be well-established to recommend usage. Credible resources include the [National Institute of Health’s Office of Dietary Supplements](https://ods.od.nih.gov/), the [Micronutrient Information Centre of the Linus Pauling Institute](https://lpi.oregonstate.edu/mic), and other reputable organisations such as the [Academy of Dietetics and Nutrition](https://www.eatrightpro.org/) and the [International Olympic Committee](https://www.olympic.org/the-ioc), all of which offer position papers on various topics related to exercise and sports nutrition, supplements and ergogenic aids.

The scientific, peer-reviewed research reviews and clinical trials available on PubMed are generally reliable resources with limitations to some studies, sometimes including a small number of participants, inadequate duration and a lack of control of influencing factors (i.e. confounding variables). Studies performed on animals without follow-up studies in humans, single studies or case studies are not considered adequate to recommend a dietary supplement. Commercials and testimonials based on anecdotal evidence are the weakest forms of evidence. The International Olympic Committee’s hierarchy of evidence for the use of dietary supplements is presented in Figure: IOC's Hierarchy of Scientific Evidence (Maughan et al., 2018).

A diagram of a pyramid

AI-generated content may be incorrect.

**Dosages, ingredient form and study populations**

In addition to a strong body of research, the formula of the product, including amounts and forms of the ingredients, should ideally match well-designed human clinical trials, which include a control group, randomisation of the supplement(s) and placebo, the measurement of relevant outcomes and a control for any confounding variables. Oftentimes, supplements are not marketed to the population that was studied in the research they claim supports their product. For example, a weight-loss supplement may be marketed to speed up fat burning based on a 'recent scientific study'. Further investigation reveals that the study was conducted in mice who consumed a thermogenic compound that has not been evaluated in humans. Additionally, supplement companies frequently tout some forms of ingredients to be superior to others, as is the case for creatine monohydrate, a well-researched ergogenic aid with over 1,000 studies, yet the data is lacking on other forms of creatine (e.g. creatine nitrate and creatine hydrochloride).

Another factor to note is the dose of the ingredients included in the product, which may not match the study protocols. For instance, creatine monohydrate has been shown to elevate muscular creatine stores when consumed at 3 to 5 grams a day over approximately 4 weeks; yet, a serving size might contain 1 gram of creatine. As noted, it is not required by law for supplement manufacturers to prove their products are safe or effective; however, companies are legally obligated to have scientific research that supports the safety and efficacy of their products and should be able to provide this documentation on request. Failure to do so is a red flag and should elicit an additional investigation prior to using or recommending the product.

Critical!

Elements of a well-designed clinical trial include the following:

* Human subjects
* Control groups
* Randomisation of the supplement(s) and placebo
* Measurement of relevant outcomes
* Control of confounding variables

**Independent testing**

Independent, third-party testing of products for the ingredient quality and identity, label accuracy, purity and disintegration is a voluntary step manufacturers can take to assure consumers that their product contains the listed ingredients in their respective amounts. The major companies in the United States that provide certification to verify the content of their supplements include Consumer Lab, U.S. Pharmacopeia (USP), Informed Choice, Banned Substances Control Group (BSCG), and NSF International (Table: Supplement Testing Companies). Consumer Lab’s quality evaluation requires that products from consumer channels be randomly tested once a year. Approval indicates the product was tested for ingredient identity, strength (amounts stated on the label), purity (free of specified contaminants) and disintegration (Consumer Lab, 2018).

Supplement Testing Companies

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| A blue and white logo  AI-generated content may be incorrect. | A close-up of a logo  AI-generated content may be incorrect. |  | A green and black logo  AI-generated content may be incorrect. | A blue circle with white text  AI-generated content may be incorrect. |
| Consumer Lab  [consumerlab.com](http://consumerlab.com/) | U.S. Pharmacopia (USP)  [quality-supplements.org](http://quality-supplements.org/) | Banned Substances Control Group  [bscg.org](http://bscg.org/) | Informed Choice  <https://www.informed-choice.org/> | NSF International  [nsf.org](http://nsf.org/) |

USP’s Dietary Supplement Verification Program ensures the product contains the ingredients and amounts listed on the label, is free from harmful levels of specified contaminants (e.g. pesticides, heavy metals or microbes), is made in a facility that is compliant to cGMPs, and will break down in the body within a specified time. Products are also tested annually to retain the USP Verified mark (U.S. Pharmacopeia, 2018).

In addition to testing for ingredient identity and strength, testing for hidden drugs and banned substances in sports is also conducted to varying degrees and standards by BSCG’s Certified Drug-Free programme, Informed Choice’s Registration Process and NSF International’s Certified for Sport programme. These programmes may include random audits of manufacturing facilities and procedures (cGMPs) and random testing of finished products. On the successful completion of the certification process, products are permitted to include the certifier’s logo and are listed on the certifier’s website.

NSF International offers a Certification for Sport programme that includes testing for banned substances listed by various sports organisations. Major League Baseball, the National Hockey League and the Canadian Football League require members to utilise only NSF Certified-for-Sport products. Several organisations, including the National Football League, the Professional Golf Association and the Collegiate and Professional Sports Dietitians Association, recommend NSF Certified-for-Sport products. Utilising independently tested products is particularly important if you are working with athletes because they can test positive for a banned substance by using tainted supplements.

However, a critical point about third-party testing companies is they do not evaluate the efficacy of the products or truthfulness of all claims companies make about their products. Nutrition Coaches, athletes and consumers are advised to seek out additional information from credible resources, such as those previously listed, and contact companies to provide information about product efficacy, including published research related to their products. The legality of supplement ingredients for athletes in their respective sports must also be investigated. Additionally, it is prudent for individuals taking medications to consult their healthcare professional prior to consuming dietary supplements as there may be potential interactions.

Coach's Corner

Guidelines for Selecting Dietary Supplements

1. Verify the ingredients are supported with solid evidence for efficacy and safety from scientific reviews, reputable organisations and/or well-designed human studies.
2. Determine whether ingredient forms and dosages in product formulas match evidence-based recommendations.
3. Check if the product is independently tested to verify label accuracy. For athletes, third-party testing for banned substances is critical.
4. Request independent research from companies that verifies the claims for their products.

Quite frequently, supplement products cannot meet all four of these guidelines. However, one example of a supplement brand that always strives to meet these criteria for their entire product line is dotFIT. Learn more about how dotFIT supports their products with independent, third-party research by exploring their [Practitioner Dietary Supplement Reference Guide (PDSRG), 3rd Edition](https://www.dotfit.com/PDSRG-Updates).

## Dietary patterns to optimise health

Despite the recommendations to choose a wide variety of nutrient-dense foods and consume an appropriate level of calories to maintain a healthy body weight, the food choices of many Americans are in sharp contrast to the *Dietary Guidelines for Americans* (DGA), resulting in the overconsumption of calories and underconsumption of essential micro-nutrients (vitamins and minerals). The 2015–2020 DGA report identified key nutrients that are under-consumed, including vitamins A, C, D and E, choline, potassium, magnesium, iron, calcium and fibre. Adverse health effects resulting from the under-consumption of calcium, vitamin D, potassium, iron and fibre were deemed a public health concern (U.S. Department of Agriculture & Health and Human Services, 2015). Although overt micro-nutrient deficiencies are rare in the United States and other developed countries, inadequate intake appears commonly.

In addition to the key nutrients identified as of public health concern by the DGA, a dietary analysis of 70 sedentary individuals and athletes revealed insufficient intakes of 3 to 15 essential micro-nutrients in every individual diet (Misner, 2006). Males lacked 40% of the vitamins and 54.2% of minerals, and females were deficient in 29% of vitamins and 44.2% of the minerals analysed. Athletes had more micro-nutrient deficiencies than sedentary counterparts and those reducing calories to lose weight were lacking more micro-nutrients than those who did not reduce calories.

Another study, which analysed 3 days of menus from four popular diets, including the South Beach diet, Atkins for Life, the DASH diet and the Best Life diet, concluded that individuals following any of these diets were highly likely to become deficient in several micro-nutrients (Calton, 2010). Each diet failed to provide the daily recommended levels of 12 to 21 micro-nutrients and there were six micro-nutrients that were deficient in all four diets – vitamin D, vitamin E, biotin, iodine, molybdenum and chromium. Considering estimates that 1/3 of adults in the United States are on a diet at any given time, coupled with the data above, it is possible that many people are at risk of developing micro-nutrient deficiencies over time.

Coach's Corner

Data shows that many Americans under-consume key vitamins and minerals that support optimal health, including vitamins A, C, D and E, choline, potassium, magnesium, iron, calcium and fibre. Underconsumption of essential nutrients is a key public health concern.

### Multivitamin and mineral supplements

Sufficient amounts of essential micro-nutrients, such as vitamins and minerals, are required for normal growth and development, metabolism and longevity. Low consumption of micronutrients may result in negative mood, impaired focus and attention span, general fatigue and lowered capacity to fight infections; yet, these symptoms are often attributed to factors other than micronutrient intake (Dong, Xun, Pe & Qin, 2011; Huskisson, Maggini & Ruf, 2007; Yokoi & Konomi, 2017). Additionally, even when not at low levels of overt deficiency, emerging data suggests that inadequate intakes of micro-nutrients below daily recommended levels may elevate risk for chronic and age-related diseases, including eye disease, osteoporosis, cancer, heart disease and Type 2 diabetes (Ames 2006; Angelo, Drake & Frei, 2015).

The proper use of dietary supplements, particularly multivitamin and mineral formulas, has been shown to help fill common and widespread nutrient gaps (Bailey, Fulgoni, Keast & Dwyer, 2012; Blumberg et al., 2017). Blumberg et al. (2017) analysed the intake of 17 nutrients in nearly 11,000 adults in the United States from either food alone, or food and a multivitamin and mineral supplement. Higher frequency of use eliminated inadequate intakes of all the vitamins and minerals examined, with the exception of vitamin D, calcium and magnesium. Hence, the use of a daily multivitamin and mineral to avoid common insufficiencies and meet recommended intakes based on age, gender and life stage appears to be an effective nutritional strategy. Achieving daily requirements for major minerals such as calcium, magnesium, iron and other essential nutrients, such as vitamin D and the omega-3 fatty acids DHA and EPA, may require separate supplementation. Although dietary supplements do not replace a healthful diet, they can help achieve recommended intakes of essential nutrients, which may play a supportive and critical role in healthy aging.

Helpful Hint

Use the values depicted in Figure: What Your Multi Should Contain to help choose a quality multivitamin and mineral formula (adapted from Schardt, 2016).

A blue and white label with white text

AI-generated content may be incorrect.

### Supplements for muscle gain and recovery

Numerous dietary supplements are made commercially available and are marketed for enhancing muscle mass, strength, weight loss, athletic performance and recovery from strenuous exercise. Other products are positioned as convenient sources of energy and protein to fuel exercise and achieve target amounts of macro- and micro-nutrients. Varying levels of evidence exist to support such claims, from anecdotal to systematic reviews of several randomised controlled trials. The data presented in this chapter is categorised as solid, moderate and weak for various ingredients purported to enhance common fitness goals and athletic performance, with a focus on the evidence and application for use for those with sufficient human data on safety and efficacy.

Athletes and avid exercisers frequently seek out methods to accelerate changes in body composition or boost training sessions and competitive events to gain a performance edge. The desire for continuous improvements in strength, physique, and performance has led to myriad supplements that tout various benefits; yet, solid evidence exists for only a few ingredients (Table: Muscle-Gain Supplements Strength of Evidence) (Kerksick et al., 2018). As such, there is general consensus that protein, creatine monohydrate and essential amino acids are supported by strong evidence for enhancing resistance-training-induced outcomes, including strength and muscle hypertrophy. The research and recommendations for use will be reviewed in this section. There is less evidence for the majority of ingredients in dietary supplements purported to enhance greater gains in muscle and improve recovery.

Muscle-Gain Supplements Strength of Evidence

| **Strong Evidence** | **Moderate / Mixed Evidence** | **Weak / Lack of Evidence** |
| --- | --- | --- |
| Protein  Creatine monohydrate  Essential amino acids | BCAAs  HMB  Phosphatidic acid | Arginine  Glutamine  ATP  Alpha-ketoglutarate  Prohormones |

**Creatine monohydrate**

Creatine monohydrate is synthesised endogenously in the liver and kidneys from amino acids and is stored primarily in muscle tissue. Its role is to regenerate intracellular ATPstores via the phosphocreatine system during high-intensity activity. Creatine can also be obtained from food, namely beef, poultry, and seafood (Table: Creatine Sources) (Tarnopolsky, 2010). Supplementation with creatine monohydrate is backed by a plethora of research studies that demonstrate its effectiveness at increasing muscular stores and enhancing muscle mass in conjunction with resistance training (Kreider et al., 2017; Kerksick et al., 2018). Greater gains in muscle tissue seem to be a result of superior training adaptations due to increased workload capacity at high intensities. When compared to controls, individuals who supplement with creatine monohydrate for 1 to 3 months have been shown to gain 1 to 2 more kilograms of mass (Volek et al., 1999; Helms, Aragon & Fitschen, 2014).

Short- and long-term studies have demonstrated the safety of creatine supplementation among healthy populations, with the only significant side effect (which is typically one of the desired side effects) being weight gain due to increases in water retention and muscle mass (Kreider et al., 1999; Kreider, 2003).

Creatine Sources

| **Source (8 oz serving)** | **Creatine Content** |
| --- | --- |
| Beef (lean) | 1.5 to 2.5 g |
| Pork | 1.5 to 2.5 g |
| Herring | 2.0 to 4.0 g |
| Salmon | 1.5 to 2.5 g |
| Milk | 0.05 g |

Typical use includes two methods that have been shown to increase muscular creatine stores by 20 to 40% (Kreider & Jung, 2011). The first method includes a loading phase lasting 5 to 7 days consuming 20 to 25 grams daily, or about 0.3 gram/kilogram of body weight in doses split throughout the day, followed by a maintenance phase that consists of consuming a daily dose of 3 to 10 grams daily, with the higher-maintenance dose likely more appropriate for individuals with greater muscle mass (Kreider et al., 2003; Kreider et al., 2017). Another method involves gradually increasing muscular stores by consuming a daily dose of 3 to 5 grams a day over 3 to 4 weeks.

The first method may result in a faster loading and more immediate performance benefit due to higher creatine stores. Co-ingesting carbohydrate (with or without protein) with creatine monohydrate increases uptake and muscular retention (Kreider et al., 2017). The duration of creatine supplementation is dependent on the individual’s desired outcome, length of high-intensity training phase, and time restrictions due to competitive events. On cessation of use, creatine stores normalise within 4 to 8 weeks (Tarnopolsky, 2010; Kreider et al., 2017).

Getting Technical

The research on creatine is extensive. Review Table: Key Research on Creatine Monohydrate for a selection of studies that produced significant results in favour of creatine supplementation.

Despite marketing claims to the contrary, other forms of creatine including creatine HCl, buffered creatine, alkalised creatine and creatine ethyl ester have not been proven to be more effective than creatine monohydrate (Spillane et al., 2009; Jager, Purpura, Shao, Inoue & Kreider, 2011). Creatine monohydrate is thought to be the most-effective dietary supplement for enhancing high-intensity training, strength and muscle mass. However, some individuals are considered non-responders and do not experience these benefits, likely due to naturally elevated muscular stores of creatine (Harris, Söderlund & Hultman, 1992).

Key Research on Creatine Monohydrate

| **Research Authors** | **Outcome Measured** | **Dosing Protocol** | **Results** |
| --- | --- | --- | --- |
| Harris et al., 1992 | Muscular creatine content of the quadriceps femoris | 5 g, 4 to 6 times/day for 4 to 10 days  N = 17; 5 females + 12 males | about 15 to 20% increase |
| Hultman et al., 1996 | Total muscular creatine stores | 5 g, 4 times/day for 6 days + 2 g/day for 30 days  3 g/day for 28 days  N = 31; males | about 20% increase in both supplementation groups compared to placebo group |
| Vandenberghe et al., 1997 | Muscular creatine stores  Strength  Fat-free mass | 5 g 4 times/day for 4 days + 5 g/day for 65 days + resistance training (10 weeks followed by detraining period)  Same protocol for placebo group  N = 19; young, sedentary females | Significant increase in phosphocreatine stores  20 to 25% increase in maximal strength  60% increase in fat-free mass |
| Volek et al., 1999 | Muscular creatine stores  Muscle fiber hypertrophy | 25 g/day for 1 week + 5 g/day for 11 weeks  Same protocol for placebo group  N = 19; resistance-trained men | 22% increase in creatine stores  6.3% increase in body mass  6.3% increase in fat-free mass  Significant increases in Type 1, 11A, and IIAB muscle fiber cross-sectional areas  Significantly greater average volume lifted in bench press in creatine group during weeks 5 through 8 |
| Kreider et al., 2003 | Creatine stores  Phosphocreatine stores | Literature review of 500 studies | Short-term supplementation of 20 g for 5 to 7 days increases total creatine by 10 to 30% and phosphocreatine by 10 to 40%. |

**Protein**

Protein provides amino acids, the building blocks of skeletal muscle, other structures, and various compounds in the body such as enzymes and hormones. Of the 20 amino acids, 9 are considered essential and must be obtained from the diet because they cannot be synthesised endogenously. Animal sources of protein provide all essential amino acids (EAAs), whereas plant sources, with the exception of soy, are limited in at least one or more essential amino acids. In general, protein sources considered to be high quality are rich in essential amino acids, are digested and absorbed well, and for exercise and athletes, are superior for supporting training outcomes such as muscle hypertrophy, fat loss and enhanced recovery.

The ingestion of high-quality protein stimulates muscle protein synthesis (MPS) and the effect is enhanced with resistance training (Jäger et al., 2017). Thus, maximally stimulating MPS may benefit those attempting to gain muscle tissue. This has been investigated extensively in humans of various ages and training experience levels. Protein intake greater than the recommended dietary allowance (RDA) of 0.8 gram/kilogram/day of body weight has been shown to help individuals performing resistance-training exercise maintain protein balance, build muscle mass and improve body composition (Aragon et al., 2017; Cintineo, Arent, Antonio & Arent, 2018; Jäger et al., 2017; Morton et al., 2018).

A systematic review of 49 randomised controlled trials with 1863 participants, who performed resistance training at least twice a week for 6 weeks or longer, revealed that protein supplementation significantly increased strength, lean body mass, and muscle size in healthy adults who were not restricting calories compared to a placebo or no supplements (Morton et al., 2018). On average, protein-supplementation-enhanced resistance training induced a lean-body-mass gain of 27% and increased the muscle fibre cross-sectional area by 38%. These increases were not further enhanced with daily protein intakes greater than 1.62 gram/kilogram of body weight (0.73 gram/pound) and were more pronounced in trained individuals. Older individuals did not appear to benefit from training-induced increases and muscle protein supplementation; however, the average dose among older subjects was 20 grams/day. It has been shown that higher dosages of up to 40 grams post-exercise are needed to achieve muscle protein synthesis rates similar to younger counterparts, likely due to the anabolic resistance among older individuals (Burd et al., 2013; Churchward-Venne, Holwerda, Phillips & van Loon, 2016; Wall et al., 2015).

The International Society of Sports Nutrition (ISSN) recommends a daily protein intake of 1.4 to 2.0 grams/kilograms of body weight to build and maintain muscle tissue for most exercisers: split evenly throughout the day, approximately every 3 to 4 hours (Jäger et al., 2017). Higher daily intakes of approximately 3.0 grams/kilograms among highly trained athletes restricting calories has been shown to preserve lean tissue and promote fat loss with no adverse health effects; however, this did not yield greater increases in lean mass compared to 2.2 grams/kilograms/day. MPS is stimulated with protein ingestion and remains elevated for 3 to 4 hours. Thus, the aim of consuming regular meals with protein is to keep the muscle synthetic response optimal and continuous throughout the day.

After resistance exercise, skeletal muscle synthetic rates remain elevated for up to 24 hours and, although the consumption of protein immediately (1 hour) after training or competition may not enhance hypertrophy if total daily intakes are met, doing so may support recovery and subsequent training and performance (Cintineo et al., 2018). Thus, the post-workout period offers an opportunity to consume a high-quality protein dose to help reach daily targets, enhance MPS and potentially benefit continuous intense training. Additionally, appetite is often diminished after intense activity and consuming a protein-rich shake may be more feasible, especially at training or competition venues.

Athletes and exercisers interested in optimising muscle protein synthesisto maximise gains in lean tissue may benefit from per-meal protein doses of 0.40 to 0.55 gram/kilogram, consumed across at least four meals to reach total daily intakes of 1.6 to 2.2 grams/kilograms (Schoenfield & Aragon, 2018). Protein sources with a full spectrum of essential amino acids and adequate amounts of leucine (1.7 to 3.5 grams per dose), the primary trigger of muscle protein synthesis, with some sources having higher amounts of leucine than others, should be selected (Table: Protein Supplement Leucine Content). Protein supplements typically contain one or more sources: milk, eggs, soy, peas or rice.

Protein Supplement Leucine Content

| **Protein Supplement Type** | **% Leucine Content** |
| --- | --- |
| Whey | 11% |
| Casein | 9.3% |
| Eggs | 8.5% |
| Soy Isolate | 8% |
| Peas | 8% |
| Wheat | 7% |
| Brown Rice Isolate | 8% |

**Whey**

Whey and casein are derived from bovine milk, comprising 20% and 80% respectively of the protein component of milk. Whey is particularly rich in EAAs (50% by weight), with the highest leucine content when compared to other animal protein sources. Due to its solubility, whey mixes easily and is digested and absorbed rapidly, rendering it a particularly popular supplement among exercisers and athletes seeking to increase or preserve muscle mass during intense training and/or dieting in preparation for competition. It is available in three main forms: concentrate, isolate and hydrolysate, all of which are widely available and marketed for inducing muscle gain.

Whey protein concentrate is the liquid fraction of milk and is typically about 80% protein with small amounts of carbohydrates, fat and lactose. It contains bioactive ingredients such as beta lactoglobulin, alpha lactalbumin and lactoferrin, which play a role in immune system function and is, therefore, less refined than the isolate form (Bell, 2000). Whey protein isolate contains a higher portion of protein by weight (90%) and is a result of additional filtration of whey concentrate, during which the bioactive compounds, fat and carbohydrates are removed. It is typically costlier than the concentrate form. Whey protein hydrolysate contains shorter amino acid chains (peptides), which are formed by adding enzymes to either whey concentrate or isolate, purportedly enhancing digestion and absorption. It is often the most expensive form of whey protein.

All forms of whey protein are rapidly digested and provide a high-quality source of protein, which can help individuals reach total-daily-protein targets and maximise muscle protein synthesis, particularly when minimising calories during weight loss or when consuming whole food sources is impractical.

**Casein protein**

Casein makes up 80% of the protein in milk. Although it is a complete protein source, it contains less leucine and is insoluble in acid, forming clots in the stomach acid, thereby leading to slower digestion and absorption. As such, casein protein supplementation has been shown to stimulate MPS to a lesser extent than whey protein supplementation and leads to lower resistance-training-induced gains in lean mass (Cribb, Williams, Carey & Hayes, 2006; Tipton et al., 2004). However, there appears to be a benefit to consuming casein protein prior to bedtime for stimulating MPS during sleeping hours. One study showed that when a pre-bedtime dose of casein protein (27.5 grams) and carbohydrate (15 grams) are combined with daytime resistance training over several weeks, muscle strength and hypertrophy are greater in healthy, young men compared to a calorie-free placebo (Snijders et al., 2015). A narrative review by Trommelen & van Loon (2016) revealed that pre-sleep protein ingestion results in adequate digestion and absorption during overnight hours, and that 40 grams of casein protein administered prior to sleep leads to greater amino acid availability and 22% higher MPS rates than a placebo among recreational athletes performing regular resistance training.

At present, the research on pre-sleep protein ingestion and its effect on MPS, strength and muscle mass has been conducted with casein. The optimal protein types and dosages have yet to be established; yet, it is clear there is potential benefit from the ingestion of protein prior to sleep for enhancing muscle protein synthesis and exercise-induced outcomes as well as reaching daily protein targets.

**Plant protein**

Plant-based protein supplements are growing in popularity and are often composed of one or more protein sources from soy, peas, rice and others. In terms of stimulating MPS, soy protein has been shown to be inferior to whey and casein due to lower leucine content, fewer essential amino acids and lower bioavailability (Tang et al., 2009). Although soy is a complete protein and fast-acting due to its rapid digestibility, its amino acids are not as bioavailable to skeletal muscle tissue compared to whey and casein protein (Devries & Phillips, 2015). Research examining the impact of plant-based proteins on muscle protein synthesis and changes in body composition has utilised primarily soy protein; thus, the data is limited (Morton et al, 2018).

In theory, a plant-based protein source rich in EAAs and leucine with high bioavailability would stimulate MPS and enhance the response to resistance exercise. A randomised controlled trial comparing two daily doses of 25 grams of supplemental pea proteins with whey protein placebo on their impact on muscle mass during 12 weeks of resistance training resulted in the whey and pea protein groups experiencing similar and significant improvements in muscle thickness compared to the placebo, demonstrating potential viability for pea protein to enhance muscle gain with additional studies needed (Babault et al., 2015).

Protein ingestion above the minimum recommended amounts (RDA) improves resistance training outcomes, including strength and greater muscle mass. Protein supplementation provides a viable means of optimising the muscle synthetic response over 24 hours with benefits appearing greater with whey and casein, which are abundant in leucine and contain the full spectrum of EAAs required to synthesise muscle tissue. Health concerns resulting from high-protein intakes, broadly defined as greater-than-minimum daily requirements of 0.8 gram/kilogram, were addressed in two 2018 systematic reviews.

Among 1358 individuals across 28 randomised, controlled trials comparing protein intakes of at least 1.5 gram/kilogram body weight or more than 100 grams per day to lower protein intakes, glomerular filtration rates did not differ between groups and do not impair kidney function in healthy individuals (Devries et al., 2018). A separate review and meta-analysis of trials and observational data had similar findings with evidence suggesting that protein intake above minimum requirements does not adversely affect blood pressure (Van Elswyk, Weatherford & McNeil, 2018). Of note is the current Acceptable Macronutrient Distribution Range (AMDR) of 10 to 35% of total daily calories from protein, which can exceed the current RDA and include previously noted optimal intakes for muscle hypertrophy.

Coach's Corner

Protein Supplementation Guidelines

* Ensure total daily intakes are met using 0.7 to 1.0 gram/pound (1.2 to 2.2 grams/kilograms). Trained athletes restricting calories may benefit from more to preserve muscle and promote fat loss.
* To maximise MPS and hypertrophy, consume four meals with 0.2 to 0.25 gram/pound (0.4 to 0.55 gram/kilogram) of body weight per meal of high-quality protein.
* There may be benefits to consuming a protein-rich meal/snack in the post-workout period, especially with heavy training volumes, multiple competitive events, or when helping to meet total daily protein targets depending on meal frequency.
* A pre-bedtime protein dose of 30 to 40 grams may help maximise MPS during sleeping hours.

### Essential Amino Acids

Essential amino acids (EAAs) provide building blocks for muscle tissue and other bodily proteins with the branched chain amino acids (BCAAs) leucine, valine, and isoleucine being the most abundant in skeletal muscle (Table: Essential Amino Acids). As previously noted, they cannot be produced in the body, and therefore, must be obtained from the diet. It is well-established that complete protein sources, which contain the greatest amounts of EAAs, are the most effective at stimulating muscle protein synthesis with a synergistic effect occurring with resistance training. Isolating EAAs from intact protein sources and delivering them in free form has also been shown to stimulate MPS. EAAs, as well as BCAAs, are commonly used supplements among those seeking improved recovery and greater gains from intense training (Tipton, Gurki, Matin & Wolfe, 1999).

Essential Amino Acids

|  |  |  |
| --- | --- | --- |
| Leucine | Isoleucine | Valine |
| Histidine | Lysine | Methionine |
| Phenylalanine | Threonine | Tryptophan |

A review of the evidence concluded that the consumption of EAAs has potential value for enhancing muscle protein synthesis when 6 to 12 grams are consumed before, after or during exercise (Kerksick et al., 2018). Borsheim, Tipton, Wolf & Wolfe (2002) showed that 6 grams of EAAs consumed as a beverage 1 and 2 hours after strenuous resistance training equally simulates muscle protein synthesis in six young (19 to 25 years), active men and women. A follow-up study conducted with six young (average age 34 years) and seven older (average age 67 years) healthy, physically active participants demonstrated that 15 grams of EAAs dissolved in a noncaloric beverage significantly increased muscle protein synthesis with no difference between age groups and independent of resistance training (Paddon-Jones et al., 2004). This is in contrast to the blunted muscle protein synthetic response to protein observed in older adults compared to younger counterparts, suggesting EAAs are an effective means to stimulate MPS and can potentially aid in preserving muscle mass and enhancing resistance training outcomes during aging.

When healthy, trained males consumed equal amounts of leucine via beverages with EAAs, BCAAs or leucine alone (during resistance exercise) greater muscle protein synthesis occurred with EAAs, indicating a synergistic effect of the complete spectrum of EAAs (Moberg et al., 2016). Furthermore, 15 grams of EAAs combined with 30 grams of carbohydrates consumed in between normal meals resulted in a greater anabolic effect than similar amounts of EAAs from a whole food source, and did not reduce the muscle synthetic response to protein-containing meals consumed throughout the day (Paddon-Jones, Sheffield-Moore, Aarsland, Wolfe & Ferrando, 2005). These findings suggest that EAAs in free form may be more readily available to elicit muscle protein synthesis than mixed meals.

Some studies have investigated the potential value of EAAs to reduce perceived muscle soreness, decrease markers of muscle damage, or help maintain force production, and thus support ongoing high-quality training sessions. A recent study demonstrated that BCAAs consumed in dosages according to LBM (0.22 gram/kilogram/day) while controlling for protein intake (1.2 gram/kilogram/day) resulted in significantly lower muscle damage, less soreness and greater force production (VanDusseldorp et al., 2018). Therefore, EAA or BCAA ingestion with adequate leucine may serve as a viable nutritional strategy to maximise MPS throughout the day among young and older individuals and may be particularly beneficial with lower protein intakes while restricting calories to promote fat loss, minimise the loss of lean tissue and support recovery from intense training.

Consuming 6 to 15 grams of essential amino acids with 1.7 to 3.5 grams of leucine may maximise MPS and reduce muscle soreness. This may be particularly helpful for those restricting calories while attempting to maintain muscle tissue and with lower protein intakes.

Essential Amino Acids (EAAs) include the branched chain amino acids (BCAAs), leucine, isoleucine and valine. Adequate leucine (1.7 to 3.5 grams) and all EAAs are required to stimulate muscle protein synthesis and build muscle tissue. If EAAs are consumed to maximise MPS, BCAAs are likely unnecessary. If the total daily protein intake is on the lower end (1.2 gram/kilogram), BCAAs may be beneficial.

**HMB (Hydroxy-Methylbutyrate)**

Hydroxy-Methylbutyrate is a byproduct of the essential branched chain amino acid, leucine, identified as the primary initiator of muscle protein synthesis. A review of the research identified modest improvements in strength and muscle gain (0.5 to 1.0 kilogram) over a period of 3 to 6 weeks of resistance training and 1.5 to 3 grams per day of calcium HMB, particularly in untrained individuals compared to those not supplementing with HMB (Kerksick et al., 2018).

Among trained individuals, it appears that the duration of supplementation may be an influencing factor on resistance training and body-composition outcomes. In a trial with 24 resistance-trained individuals randomised to either 3 grams per day of HMB free acid or a placebo for 8 weeks of progressive resistance training, followed by 2 weeks of an overreaching cycle and 2 weeks of tapered training, the supplement group significantly increased strength and lean body mass compared to the placebo (Wilson et al., 2014).

Among 24 highly trained male combat athletes (wrestlers, judokas and Brazilian jiu-jitsu practitioners), 12 weeks of supplementing with 3 grams per day of calcium HMB resulted in a significant increase in fat-free mass and significant decrease in fat mass compared to 12 weeks of placebo treatment (Durkalec-Michalski, Jeszka & Podgórski, 2017). Documented benefits of HMB supplementation on strength and muscle mass involve the ability of HMB to reduce muscle damage induced by exercise predominately in older, untrained individuals and highly trained athletes undergoing periods of extreme physical stress, such as severe caloric restriction and intense exercise (Holecek, 2017; Rowlands & Thomson, 2009).

However, a systematic review and meta-analysis of six randomised controlled trials and 193 participants on the effect of HMB supplementation on body composition and strength did not find any impact in trained and competitive athletes (Sanchez-Martinez, Santos-Lozano, Garcia-Hermoso, Sadarangani & Cristi-Montero, 2018). One review of nine randomised controlled trials with 3 grams/day of HMB free-acid supplementation with resistance training concluded HMB may reduce markers of muscle damage and enhance strength and muscle mass (Silva et al., 2017).

Another systematic review and meta-analysis of 18 studies and over 500 participants involving HMB supplementation and recovery concluded HMB improved markers of muscle damage in a time-dependent manner, with significant improvements observed with at least 6 weeks of supplementation (Rahimi, Mohammadi, Eshaghi, Askari & Miraghajani, 2018). Hence, the body of literature suggests HMB’s benefit as an anticatabolic and recovery agent with potential for counteracting muscle loss during aging (Molfino et al., 2013; Phillips, 2015; Woo, 2018). Daily doses of 3 to 6 grams are often split across the day with meals and bedtime to enhance retention, and use for up to 8 weeks appears safe (Nissen et al., 2000).

## Supplements for fat loss

With overweightness and obesity among U.S. adults and youth at an all-time high and steadily increasing (Figure: Trends in Obesity), coupled with the challenge to improve eating and exercise habits and maintain weight loss over the long haul, the desire and appeal for a product to enhance weight loss is unsurprising. One survey of 3500 U.S. adults revealed that among those making a serious attempt to lose weight, over 1/3 (33.9%) use at least one dietary supplement (Pillitteri et al., 2008). This study also revealed widespread misunderstanding regarding the regulation of dietary supplements, demonstrating that many believe the safety and efficacy of supplements are determined prior to their sale and advertising.

Widespread use and misperceptions of dietary supplement manufacturing underscores the need to guide and educate clients accordingly. Despite the plethora of weight-loss supplements in the marketplace, the abundance of strong evidence to support their use is limited. This section will review the research on popular dietary supplements marketed for weight loss and, where appropriate, their applications for use.

A graph of a number of years

AI-generated content may be incorrect.

### Stimulants

Weight-loss supplements, whether in pill, capsule or powder form, often contain one or more ingredients that stimulate the nervous system and are routinely advertised as fat burners due to their impact on metabolism. Commonly used stimulants include caffeine, green tea extracts, ephedra, bitter orange and capsaicinoids and may be combined with herbs, other plant-derived ingredients, amino acids and minerals.

Herbal sources of caffeine or other stimulants may be listed as an ingredient without including the particular stimulant and the amount. Furthermore, multi-ingredient weight-loss products are abundant in the marketplace, yet are rarely tested in clinical trials, making it difficult to determine the safety and efficacy for consumers and practitioners alike.

**Caffeine**

Caffeine (1,3,7-trimethyl-xanthine) is a naturally occurring substance in coffee beans, kola nuts, guarana seeds, yerba mate and tea leaves, and it is also synthesised in a lab as caffeine anhydrous. It stimulates the nervous system and has been shown to modestly increase daily energy expenditure, decrease energy intake, reduce perceived-effort-level of exercise, and improve feelings of energy and alertness (Acheson et al., 2004; Harpaz, Tamir, Weinstein & Weinstein, 2017).

Using a moderate caffeine dose of 4 milligrams/kilograms of body weight from coffee, significant increases in resting metabolic rate (RMR) ranging from 4.9 to 12% were observed in normal-weight and obese individuals, with a greater increase occurring among normal-weight persons (Acheson et al., 1980; Bracco, Ferrarra, Arnaud, Jequier & Schutz, 1995). Similarly, a single 100-milligram dose of caffeine increased resting metabolism by 3 to 4% for 2.5 hours in lean and formerly obese participants (Dulloo et al., 1989). Over 12 hours, taking a 100-milligram dose every 2 hours increased energy expenditure by 8 to 11% in both groups. This equated to a significant daily increase of 79 calories in the formerly obese participants and 150 calories in the lean subjects. A meta-analysis of six well-designed studies revealed caffeine-only and caffeine with catechins from tea significantly increase 24-hour energy expenditure by 4.8 and 4.7%, respectively, compared to the placebo. A caffeine-catechin mixture also significantly increased fat oxidation (Hursel et al., 2011).

Caffeine appears to work synergistically with exercise to increase energy expenditure and fat oxidation and potentially decrease acute energy intake. Active healthy adults consumed a moderate dose of caffeine (3 milligrams/kilograms) 90 minutes before an hour of moderate-intensity exercise and 30 minutes post-exercise, which resulted in significantly higher energy expenditure and fat oxidation. Fewer calories were consumed 2 hours later compared to a meal consumed after an exercise bout without caffeine ingestion (Schubert et al., 2014).

Other studies have generated similar findings among sedentary women with higher dosages (5 to 10 milligrams/kilograms) consumed prior to moderate exercise, resulting in greater energy expenditure compared to exercise without caffeine (Donnelly & McNaughton, 1992; Wallman, Goh & Guelfi, 2010). Caffeine in coffee at a dosage of 6 milligrams/kilograms reduced how much overweight and obese participants consumed 3 hours later and the next day compared to water and a lower dose of caffeine (3 milligrams/kilograms). Another study found that, compared to a placebo, 300 milligrams of caffeine given 30 minutes prior to unlimited access to food reduced intake in men (by 22%) but not women (Gavrieli et al., 2013; Tremblay, Masson, Leduc, Houde & Depres, 1988).

Other research found no immediate impact of caffeinated coffee on energy intake in healthy males (Gavrieli et al., 2011). An apparent benefit to caffeine ingestion is a decreased sense of effort associated with exercise and an increase in physical performance (Harpaz et al., 2017). This has relevant practical application to exercise enjoyment and subsequent adherence, particularly during the early stages of exercise adoption and during weight- and fat-loss plateaus.

Caffeine appears to be a viable weight-loss tool; however, fat-burner supplements often include other ingredients, including green tea, capsaicin, bitter orange and ephedra (which is now banned in the United States). Green tea extracts, primarily EGCG, in combination with caffeine have been shown to increase metabolism and fat oxidation and to modestly boost weight loss and reduce waist circumference (Bérubé-Parent, Pelletier, Doré & Tremblay, 2005; Dulloo et al., 2011; Hursel et al., 2011; Phung et al., 2010) However, green-tea extracts alone do not appear to have the same impact (Janssens, Hursel & Westerterp-Plantenga, 2015; Thielecke et al., 2010).

A systematic review of 13 randomised, controlled trials analysing the effect of caffeine on weight loss determined a dose-response of caffeine on reductions in fat mass, weight and body-mass index, suggesting caffeine’s viability to aid in promoting weight and fat loss (Tabrizi et al., 2018). Overall, the research shows that caffeine in moderate doses increases energy expenditure at rest and exercise, and may decrease energy intake, and therefore, appears to serve as a safe thermogenic weight-control aid among healthy adults. See Figure: Caffeine Sources and Content for the average amounts of caffeine contained in various popular sources.

A table with blue and white text

AI-generated content may be incorrect.

One of the common misconceptions around caffeine is the notion that caffeine use at normal and recommended intake causes dehydration; yet, this has not been proven in the research (Goldstein et al., 2010; Maughan & Griffin, 2003). A minor diuretic effect may occur at rest but does not negatively impact fluid balance during exercise. Adult intake of caffeine up to 400 to 500 milligrams per day appears safe in healthy individuals, but adverse side effects, including elevated heart rate, increased blood pressure, jitteriness, nervousness and gastrointestinal distress, may occur and are more likely at higher doses (>500 milligrams) and among novel users (European Food Safety Authority, 2015; Torpy & Livingston, 2013; U.S. FDA, 2013). Doses over 10,000 milligrams are considered fatal.

The American Medical Association recommends that teenagers limit daily intake of caffeine to 100 milligrams/day (Torpy & Livingston, 2013). Because the half-life of caffeine in healthy adults is 5 to 6 hours, increased sleep latency may occur if taken late in the day.

Combining other sources of caffeine - including energy drinks; coffee; and herbal ingredients such as ma huang (ephedra), citrus aurantium (bitter orange) or other stimulants - can exacerbate side effects and is not recommended. Side effects of stimulants associated with green tea extracts include nausea, stomach upset and increased blood pressure (Jurgens et al., 2012).

Critical!

Caffeine intake up to 400 to 500 milligrams/day appears safe in healthy adults. Higher doses and combining with other stimulants may result in adverse side effects such as jitteriness, insomnia and stomach upset. Doses over 10,000 milligrams are considered fatal.

Coach's Corner

Low to moderate doses of caffeine at 3 to 4 milligrams/kilograms of body weight, not to exceed 400 to 500 milligrams/day, modestly increases daily energy expenditure, decreases food intake and may help support healthy weight management.

**Other stimulant ingredients**

The stimulants p-synephrine, the active ingredient extracted from bitter Seville oranges (citrus aurantium), and ephedrine, derived from a native Chinese plant (ma huang), are commonly included in weight-loss supplements often in combination with caffeine or other ingredients. Ephedra was banned as an ingredient in dietary supplements in 2004 by the U.S. FDA due to safety concerns, but may still be commercially available through various websites. P-synephrine is structurally similar to ephedrine and is often marketed as an ephedra-free fat-loss aid due to its apparent stimulatory effect on the central nervous system, energy expenditure and mild suppression of appetite (Stohs, Preuss & Shara, 2012).

The safety of p-synephrine has been called into question after two small studies with 25 total participants reported increases in heart rate and blood pressure (Bui, Nguyen & Ambrose, 2006; Haller, Benowitz & Jacob, 2005). The trial conducted by Bui et al. was a randomised, crossover study with 15 healthy adults who consumed one dose of bitter orange (900 milligrams standardised to 6% synephrine) or a placebo. Conversely, a small trial with 20 healthy subjects demonstrated that a 50-milligram dose of p-synephrine increased resting metabolism by 65 calories compared to a placebo with no adverse effects on mood, heart rate or blood pressure (Stohs et al., 2011). Additionally, two larger and longer double-blind, placebo-controlled trials with healthy subjects taking 49 milligrams of p-synephrine once or twice a day alone or in combination with other herbs for 2 months observed no significant changes in heart rate, blood pressure or blood chemistry (Kaats, Miller, Preuss & Stohs, 2013; Shara, Stohs & Mukattash, 2016).

The authors of one review of over 20 published and unpublished studies with over 350 subjects taking p-synephrine in doses up to 80 milligrams/day with or without caffeine in doses of 132 to 528 milligrams/day or other ingredients for up to 12 weeks concluded that p-synephrine alone, or as part of a multi-ingredient supplement, increases energy expenditure and resting metabolic rate (Stohs, Preuss & Shara, 2012). Jung et al. (2017) studied the effects of a multi-ingredient caffeine-containing (284 milligrams) pre-workout supplement with and without 20 milligrams of p-synephrine or a placebo on exercise performance and resting energy expenditure in 75 healthy active adults. It found no adverse effects on heart rate, blood pressure, kidney function or liver enzymes relative to baseline values. Both treatment groups experienced increases in resting energy expenditure, greater readiness to exercise with no improvements in muscular endurance or anaerobic sprint capacity compared to the placebo group, and no additional benefits of p-synephrine.

A 2017 review of approximately 30 studies in over 600 normal-weight and overweight human subjects concluded that p-synephrine does not have negative effects on the cardiovascular system at daily doses up to 100 milligrams and acts as a non-stimulatory thermogenic, with no serious adverse events being directly attributable to p-synephrine; however, favourable changes in body weight have not been demonstrated (Stohs, 2017).

It is important to note that synthetic forms of p-synephrine are prohibited for use in the United States and include methylsynephrine, isopropyl-norsynephrine and t-butyl-norsynephrine, which are considered as adulterants in dietary supplements. Although the literature to date has shown small changes in energy expenditure with the bitter orange extract, p-synephrine alone, and in combination with various other ingredients, changes in body weight are less apparent and require further investigation with longer, larger-scale studies at varying doses and to discover whether meaningful weight loss can be safely achieved.

**Capsaicin**

Capsaicin is one of five naturally present capsaicinoids in red chili peppers and is purported to be a natural weight control due to its ability to stimulate thermogenesis, increase body temperature and decrease food intake (Belza & Jessen, 2005; Westerterp-Plantenga et al., 2006; Whiting, Derbyshire & Tiwari, 2012). Janssens et al. (2013) administered 2.56 milligrams of capsaicin to 15 normal-weight and overweight individuals before meals three times a day during a 25% caloric deficit and observed a significant increase in fat oxidation over a 36-hour period. Others have observed acute increases in energy expenditure between 5 and 20% with capsaicin intake, while others have not observed an effect, possibly due to varying doses, study protocol and/or small sample sizes (Saito & Yoneshiro, 2013). Additional research is required to determine whether capsaicin supplementation can result in elevated energy expenditure over extended periods.

Capsaicin’s potential as a viable weight-loss aid may be due to its effect on appetite and food intake. A small study conducted by Janssens, Hursel and Westerterp-Plantenga (2014) analysed the effect of capsaicin ingestion with meals three times a day while subjects were in energy balance and during a 25% calorie restriction. During energy balance, there were significantly greater feelings of fullness and satisfaction with capsaicin consumption and a 30% reduction during dinner. During caloric restriction, participants reported a marked decrease in the desire to eat after dinner compared to a control group, potentially mitigating the negative impact weight loss has on appetite.

A systematic review of eight randomised controlled trials on the impact of capsaicin ingestion on food intake in normal-weight and overweight adults found that a minimum dose of 2 milligrams consumed prior to meals significantly reduced intake by 74 calories compared to a placebo (Whiting, Derbyshire & Tiwari, 2014). A 12-week randomised, placebo-controlled trial with overweight individuals who supplemented with 4 milligrams of capsaicinoids daily resulted in significantly lower reported intake (257 calories/day), and those who consumed a lower daily dose (2 milligrams) experienced an improved waist-to-hip ratio compared to the placebo group. However, the 4 milligrams/day dose resulted in gastrointestinal distress in 23% of the subjects and no significant improvements in body weight were observed (Urbina et al., 2017).

A review of 20 studies involving 563 participants on the potential for capsaicin and capsaisinoids to influence body weight concluded that regular consumption significantly reduces appetite and energy intake, raises daily energy expenditure by 50 calories and significantly decreases abdominal fat, potentially leading to meaningful weight loss after 1 to 2 years of use (Whiting, Derbyshire & Tiwari, 2012).

Coach's Corner

Capsaicin may have a slight positive impact on energy expenditure, appetite and food intake when consumed in 2- to 4-milligram doses before meals.

Capsaicin ingestion prior to meals appears to have a modest impact on both sides of the energy-balance equation, potentially serving as a useful aid to help manage appetite and slightly increase daily expenditure. Capsaicin is considered safe when used in the amounts studied, with 4 milligrams/day resulting in reports of gastrointestinal distress, elevated insulin levels and lower HDL cholesterol levels among some study participants.

### Starch / fat blockers and other common weight loss ingredients

Various ingredients have been investigated for their potential to decrease absorption of macro-nutrients and their respective calorie content to promote weight loss and are routinely included in supplements as fat blockers or carbohydrate/starch neutralisers. Phaseolus vulgaris, extracted from white kidney beans, inhibits the action of the digestive enzyme amylase, thus interfering with the digestion of and absorption of carbohydrates and potentially preventing absorption (Obiro, Zhang & Jiang, 2008).

Daily dosages of Phaseolus vulgaris ranging from 500 to 3000 milligrams for up to 12 weeks have been shown to modestly enhance weight loss, albeit inconsistently. In a randomised, double-blinded, placebo-controlled trial with 60 overweight subjects, those who consumed a proprietary form (Phase 2) before a high-carbohydrate meal lost significantly more weight (6.4 lbs/2.9 kg) compared to subjects receiving the placebo (0.77 lbs/0.34 kg) after 30 days (Celleno, Tolaini, D’Amore, Perricone & Preuss, 2007).

Chitosan is another blocker supplement manufactured from shellfish. It is marketed as a fat blocker due to its ability to prevent absorption of dietary fat by binding to it in the intestinal tract (Rios-Hoya & Gutierrez-Salmean, 2016). One review of 15 trials and 1219 participants concluded that chitosan results in significantly greater weight loss of 3.7 lbs (1.68 kg) over 6 months, but many of the trials have been of poor quality (Jull et al., 2008). A 2018 meta-analysis of 14 randomised, controlled trials revealed that using chitosan (0.34 to 3.4 grams/day) for 4 to 52 weeks compared to a placebo slightly reduces body weight (weighted mean difference of 1.01 kilogram) in overweight and obese subjects (Moraru, Mincea, Frandes, Timar & Ostafe, 2018). Other commonly used ingredients in weight-loss supplements include conjugated linoleic acid (CLA), L-carnitine, chromium, green coffee bean extract and hydroxycitric acid or HCA (garcinia cambogia), all of which are either lacking in well-designed research or have shown virtually no impact on body weight (Manore, 2012).

### Meal-replacement formulas

The use of protein-rich shake formulas has been shown to be an effective strategy for reducing caloric intake and supporting weight loss and weight-loss maintenance (Heymsfield, 2010). A review of six randomized, controlled interventions on the effect of utilizing reduced isocaloric diets with one to two liquid meal replacements or regular foods for at least 12 weeks revealed that overweight or obese adults lost significantly more weight after 3 months and 1 year with no reports of adverse events and better adherence in the partial-meal replacement group (Heymsfield et al., 2003). Other work has demonstrated the use of meal replacements for up to a year to increase total protein intake and enhance weight loss and fat mass while preserving fat-free mass in obese subjects with metabolic syndrome (Chaiyasoot et al., 2018; Fletchner-Mors et al., 2010).

In a randomised trial with young, overweight men in a 40% calorie deficit combined with resistance training, high-intensity interval training, or sprint interval training 6 days a week, subjects consumed either a low-protein diet (1.2 gram/kilogram) or high-protein diet (2.4 grams/kilograms) using whey protein beverages for 4 days (Longland, Oikawa, Mitchell, Devries & Phillips, 2016). The high-protein group lost more body fat and gained significantly more lean body mass compared to the lower-protein group, which maintained lean body mass. This data and others demonstrate the value of higher protein intakes and protein-rich shakes for promoting favourable changes in body composition during weight loss.

Meal replacements appear to offer multiple benefits, including portion control and the ability to induce a calorie deficit, a method for increasing protein intake to aid in satiety along with providing structure, and convenience for weight-loss plans. The Academy of Nutrition and Dietetics identifies the use of meal replacements as an evidence-based strategy for weight loss and maintenance in overweight and obese adults (Raynor & Champagne, 2016). Additionally, meal replacements offer an opportunity to increase the diet quality of clients by adding in nutrient-rich foods such as fruits, vegetables, and calcium- and vitamin D-rich beverages.

Coach's Corner

Supplements promoted as fat burners have a limited impact on weight loss, with most ingredients lacking quality evidence. However, the use of protein-rich meal replacements one to two times/day has been shown to improve weight-loss success, body composition and maintenance of a healthy body weight.

## Performance-enhancing supplements

Dietary supplements aimed at enhancing athletic or exercise performance typically target mechanisms that are involved with inducing fatigue in the various energy systems: the phosphocreatine system and glycolysis, which are primary during high-intensity exercise of short duration or with repeated bouts of high-intensity effort over a prolonged period (i.e. team sports), and the aerobic energy system, which dominates endurance activities. Delaying or reducing fatigue in these systems can prolong maximal effort and increase time to exhaustion, thus, leading to improved measures of performance.

The ability of supplements to increase tolerance to intense training could lead to greater work capacity and improve strength, power and endurance. Performance-enhancing products are considered to be ergogenic aids and are available as liquids, powders, bars, tablets and more. A handful of ingredients have solid evidence to support their use, including creatine monohydrate, caffeine, beta alanine and sodium bicarbonate. The various mechanisms, evidence, and applications for their use will be discussed.

Many others have limited, weak, or no evidence to support use at this time, and are listed in Table: Performance Supplements Strength of Research based on several extensive reviews on dietary supplements and athletic performance, including the "IOC Consensus Statement: Dietary Supplements and High-Performance Athlete" (Maughan et al, 2018), the scholarly review “Evidence-Based Supplements for the Enhancement of Athletic Performance” published by the International Journal of Sport Nutrition and Exercise Metabolism (Peeling, Binnie, Goods, Sim & Burke, 2018), the International Society of Sports Nutrition’s "Exercise & Sports Nutrition Review Updates: Research & Recommendations" (Kerksick et al., 2018, and "The Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and Athletic Performance" (Thomas, Erdman & Burke, 2016). In addition to understanding the efficacy and safety of dietary supplements, Nutrition Coaches and athletes should thoroughly review the rules regarding dietary supplements and banned substances set forth by their sport’s governing body and should ensure products considered for use are independently tested for such banned substances.

| **Moderate/Mixed** | **Weak** | **Banned** |
| --- | --- | --- |
| BCAAs  Carbohydrate/Protein Shakes  Citrulline  Essential Amino Acids  Glycerol  HMB  Nitrate  Quercetin  Taurine | Arginine  Carnitine  Deer Antler Velvet  Glutamine  MCTs  Ribose | Androstenedione  Dimethylamylamine (DMAA)  1,3-dimethybutylamine (DMBA) |

### Creatine Monohydrate

Creatine monohydrate, as previously described, is supported by hundreds of studies that not only demonstrate its ability to increase strength and muscle gain but also its performance-enhancing effects for any activity during which the phosphocreatine system is heavily taxed. Hence, sports that require repeated short bursts of high-intensity activity, such as soccer, basketball, rowing, rugby, and individual sports such as tennis and sprinting, would potentially benefit from creatine (Kreider et al., 2017; Maughan et al., 2108; Peeling et al., 2018).

Kreider’s 2003 review revealed that 70% of the 300 studies on the effects of creatine supplementation on performance reported significant improvements, and none reported significant negative impacts on performance. Ergogenic findings included 5 to 15% improvement in maximal power/strength, 1 to 5% improvement in single-effort sprints and even greater benefit (5 to 15%) in repetitive sprint performance.

For example, young, trained males were randomised to consume 20 grams of creatine monohydrate for 5 days or a placebo. The creatine group experienced significant improvements in six 60-metre sprints and 100-metre sprints (Skare, Skadberg & Wisnes, 2001). Among highly trained junior swimmers with an average age of 16 years, 5 days of creatine use at 20 grams/day led to significantly reduced times in two maximal 100-meter races compared to the placebo (Juhasz, Györe, Csende, Rácz & Tihanyi, 2009). Two more recent systematic reviews on randomised, placebo-controlled trials had similar findings on strength performance. For exercises lasting less than 3 minutes with more pronounced effects in activities less than 30 seconds, creatine supplementation enhanced lower-body strength performance in over 60 studies with over 1200 participants and upper-body strength performance in over 53 studies and 1100 participants (Lanhers et al., 2015; Lanhers et al., 2017). Performance improvements in endurance exercise are not as well-supported; however, creatine may help enhance glycogen synthesis and aid in thermoregulation due to its ability to draw fluid into muscle (Cooper, Naclerio, Allgrove & Jimenez. 2012; Kreider et al., 2017).

The ability to train more intensely and with greater workloads over time enables users to improve muscular power, strength and lean mass, which has been demonstrated in males and females across a wide range of age groups, including adolescents and older adults (Kreider et al., 2017). Nine weeks of creatine supplementation and resistance training in elite football players resulted in significant differences in strength, anaerobic power and capacity, lean body mass and body weight compared to the placebo and control groups (Bemben, Bemben, Loftiss & Knehans, 2001).

A large body of work on the safety of creatine supplementation indicates that it does not result in muscle cramps, heat illness, dehydration or any other adverse health effect with daily dosages ranging from 0.3 to 0.8 gram/kilogram of body weight for up to 5 years for individuals of various ages (Schilling et al., 2001; Kreider et al., 2017). An extensive discussion on the safety of creatine and clinical applications, such as neurodegenerative diseases, ischemic heart disease and Type 2 diabetes, is presented in the International Society of Sports Nutrition’s position stand (Kreider et al., 2017).

**Caffeine**

Caffeine is often included in pre-workout type supplements in the purified, anhydrous form. In addition to caffeine’s stimulatory effect on the nervous system, it also blocks adenosine receptors, thus resulting in mental alertness and other cognitive benefits. Caffeine ingestion prior to intense exercise reduces rates of perceived exertion, lowers pain, raises endorphin release and improves fatigue resistance (Maughan et al., 2018). It has been well-studied and shown to be an effective ergogenic aid in short-term single and repeated bouts of maximal strength and power, intermittent team sports and endurance exercise (Goldstein et al., 2010; Grgic, Mikulic, Schoenfeld, Bishop & Pedisic, 2018).

Among trained cyclists, those given low (100 mg) and moderate (200 mg) dosages of caffeine consumed during exercise, time trials were completed significantly faster compared to a trial with a placebo, with the moderate dose rendering better improvements than the low dose (Talanian & Spriet, 2016). A systematic review, including 21 studies on endurance time trials ranging from 5 to 150 minutes across a variety of sports, found that 3 to 6 milligrams/kilograms of caffeine consumed before or during exercise improved performance by 3.2% on average, with a range between 0.3 to 17.3%. This range implies high variability in individual responses to caffeine and/or varying methods utilised across studies (Ganio, Klau, Casa, Armstrong & Maresh, 2009).

Among athletes who participate in team sports requiring repeated sprints over a prolonged period, 6 milligrams/kilograms of caffeine consumed an hour before exercise trials resulted in 8.5% greater work performed and 7% higher peak power compared to a placebo (Schneiker, Bishop, Dawson & Hackett, 2006). These findings were later replicated with semi-professional rugby players who consumed 300 milligrams of caffeine or a placebo prior to their trials (Wellington, Leveritt & Kelly, 2017).

A review on the impact of caffeine supplementation on resistance exercise concluded that 3 to 9 milligrams/kilograms ingested 60 minutes prior to activity improves maximal strength, power, muscular endurance and ratings of perceived exertion, with equivocal findings for pain perception and most of the research conducted among males utilising caffeine anhydrous in a pill or powdered form (Grgic et al., 2018).

The overall body of evidence points to dosages of 3 to 6 milligrams/kilograms of body weight consumed approximately an hour before resistance training or exercise with short, high-effort bursts. Lower doses during endurance activities have also been utilised successfully; the effectiveness of use diminishes over time according to some, but not others (Ganio et al., 2009; Goldstein et al., 2018). Intakes above 9 milligrams/kilograms of body weight offer no additional benefits, are likely to increase the risk of side effects, and may lead to a positive doping test by the International Olympic Committee (IOC) or National Collegiate Athletic Association (Burke, 2008).

Caffeine appears to promote urine flow, but there is no evidence that it disrupts fluid balance or causes dehydration at the recommended doses (Goldstein et al., 2010). As noted, daily intakes of over 400 to 500 milligrams may cause side effects, including irritability, nausea, insomnia and restlessness. Caffeine is contraindicated among those with heart disease, hypertension, thyroid disease and anxiety, and is not recommended during pregnancy and lactation. Individuals who are taking medication should consult with their physician for possible interactions.

Coach's Corner

Caffeine, particularly in anhydrous form, is an established ergogenic aid for strength, power, intermittent high-intensity and endurance activities using doses of 3 to 6 milligrams/kilograms of body weight consumed an hour before exercise, or lower doses of 1.5 to 3 milligrams/kilograms taken during endurance exercise.

**Beta Alanine**

Beta alanine is a nonessential amino acid naturally present in animal meats and produced in the liver. It combines with the amino acid histidine to form carnosine. It is a compound in skeletal muscle that reduces fatigue during high-intensity exercise by buffering the drop in pH due to hydrogen ions that are produced when glycogen is broken down to lactic acid. As such, increasing carnosine levels in skeletal muscle via beta alanine supplementation would benefit activity that relies on glycolysis for energy such as weight lifting, football, soccer and rowing. Daily intake of 4 to 6 grams over 4 to 10 weeks has been shown to elevate muscular carnosine levels significantly among trained athletes and untrained individuals, with wide variation in the degree of increase (Baguet et al., 2009; Harris et al., 2006; Trexler et al., 2015).

Performance improvements result from less fatigue during intense activity of short to moderate duration (1 to 4 minutes). The IOC’s recommendation is based on weight (about 65 milligrams/kilograms) to be ingested in doses of 0.8 to 1.7 grams every 3 to 4 hours for 10 to 12 weeks, noting the potential for meaningful performance benefits for continuous or intermittent activity lasting 30 seconds to 10 minutes (Maughan et al., 2018). Theoretically, supplementation would allow resistance exercise workloads to increase, leading to greater adaptations such as strength, power and lean mass gain, but this has yet to be determined. Although beta alanine appears to be safe in the recommended dosages noted for healthy individuals, reported negative side effects include skin tingling and rashes, which appear to be harmless and are minimised with divided doses (Trexler et al., 2015).

For healthy individuals who perform primarily high-intensity exercise lasting 30 seconds to 10 minutes, beta alanine supplementation may offer a performance benefit. Typical use includes a 2- to 4-week loading phase using 4 to 6 grams daily in divided doses. Skin tingling, a phenomenon known as paraesthesia, is a reported side effect and may be minimised by taking daily doses in two to three smaller servings throughout the day and may diminish with continued use.

**Sodium Bicarbonate**

Sodium bicarbonate, commonly known as baking soda, aids in buffering the acidity in the blood due to the production of hydrogen ions during sustained strenuous exercise, thereby potentially reducing fatigue and enhancing performance during short-term and intermittent strenuous exercise such as sprinting, tennis and boxing. Several short-term trials have established a modest enhancement of athletic performance (McNaughton, Gough, Deb, Bentley & Sparks, 2016). A meta-analysis of 38 studies revealed a 1.7% improvement in a 1-minute sprint performance and a 2.7% improvement in repeated sprint performance using a sodium bicarbonate dose of 0.3 gram/kilogram (Carr, Hopkinds & Gore, 2011).

The overall body of evidence indicates pre-exercise dosages ranging from 0.2 to 0.4 gram/kilogram of body weight, which equates to 3 to 5 teaspoons of baking soda approximately 1 to 2.5 hours before activity improves short-term, high-intensity exercise performance by approximately 2% with benefits diminishing beyond 10 minutes (Siegler, Marshall, Bray & Towlson, 2012; Maughan et al., 2018). Short-term use appears safe, but unpleasant taste and stomach upset are widely reported and are potentially eliminated with split doses or consumption of small amounts of carbohydrate (Carr, Hopkins & Gore, 2011). Therefore, trial experimentation during practice sessions is recommended to assess tolerance.

Sodium bicarbonate acts as a buffering agent during high-intensity training between 60 seconds and 10 minutes. Typical use includes single doses of 0.2 to 0.4 gram/kilogram body weight taken 1 to 2.5 hours before exercise, or split doses over 3 hours. GI upset is reported with use and may be alleviated with split doses and/or ingestion with carbohydrates.