15.6: Fitness Supplements and Steroids

Bodybuilding supplements are dietary supplements specifically marketed to those involved in bodybuilding, weightlifting, and athletics. Among the most widely used are vitamins, protein, branched-chain amino acids (BCAA), glutamine, essential fatty acids, meal replacement products, creatine, weight loss products and testosterone boosters. Supplements are sold either as single ingredient preparations or in the form of "stacks" - proprietary blends of various supplements marketed as offering "synergistic advantages". While many bodybuilding supplements are also consumed by the general public, their salience and frequency of use may differ when used specifically by bodybuilders. They may be marketed as a product to replace meals, enhance weight gain, promote weight loss or improve athletic performance. Annual sales of sport nutrition products in the US is over $2.7 billion (US) according to Consumer Reports.

History

Athletes in ancient Greece were advised to consume large quantities of meat and wine. A number of herbal concoctions and tonics have been used by strong men and athletes since ancient times across cultures for the enhancement of strength, vigor, prowess, and stamina. In the 1910s, Eugen Sandow, widely considered to be the first modern bodybuilder in the West, advocated the use of dietary control to enhance muscle growth. Later, bodybuilder Earle Liederman advocated the use of "beef juice" or "beef extract" (basically, consomme) as a way to enhance muscle recovery. In the 1950s with recreational and competitive bodybuilding becoming increasingly popular Irvin P. Johnson began to popularize and market egg-based protein powders marketed specifically at bodybuilders and physical athletes. The 1970s and 1980s marked a dramatic increase in the growth of the bodybuilding supplement industry, fueled by the widespread use of modern marketing techniques and a marked increase in recreational bodybuilding.

In October 1994, the Dietary Supplement Health and Education Act (DSHEA) was signed into law in the USA. Under DSHEA, responsibility for determining the safety of the dietary supplements changed from government to the manufacturer and supplements no longer required approval from the U.S. Food and Drug Administration (FDA) before
distributing the product. Since that time manufacturers did not have to provide FDA with the evidence to substantiate safety or effectiveness unless a new dietary ingredient was added. It is widely believed that the 1994 DSHEA further consolidated the position of the supplement industry and lead to additional product sales.

Controversies of Fitness Supplements

**Mislabeling:** According to University of Helsinki food safety professor Marina Heinonen, more than 90% of dietary supplement health claims are incorrect. While many of the claims are based on scientifically based physiological or biochemical processes, their use in bodybuilding parlance is often heavily colored by bodybuilding lore and industry marketing and as such may deviate considerably from traditional scientific usages of the terms. In addition, ingredients listed have been found at times to be different from the contents. In 2015, Consumer Reports reported unsafe levels of arsenic, cadmium, lead, and mercury in several of the protein powders that were tested. Other studies in 2013 showed that one-third of the supplements tested contained unlisted steroids. In 2015 a CBC investigative report found that protein spiking (the addition of amino acid filler to manipulate analysis) was not uncommon, however many of the companies involved challenged these claims.

**Health problems:** The US FDA reports 50,000 health problems a year due to dietary supplements and these often involve bodybuilding supplements. For example, the "natural" best-seller Craze, 2012's "New Supplement of the Year" by bodybuilding.com, sold in Walmart, Amazon etc., was found to contain undisclosed amphetamine-like compounds. Also, other products by Matt Cahill have contained dangerous substances causing blindness or liver damages, and experts say that Cahill is emblematic for the whole industry.

**Liver damage:** The incidence of liver damage from dietary supplements has tripled in a decade, the majority of these involved bodybuilding supplements. This resulted in liver transplants and, in some cases, death to the patient. Some have argued that the liver damage is more often caused by prescription drugs rather than supplements.

**Lack of effectiveness:** In addition to being potentially harmful, some have argued that there is little evidence to indicate any benefit to using bodybuilding supplements. For example, according to the IOC, no consensus had been reached in determining whether an individual in exercise training benefits from protein and amino acid supplements. "In view of the lack of compelling evidence to the contrary, no additional dietary protein is suggested for healthy adults undertaking resistance or endurance exercise".

Protein

Bodybuilders may supplement their diets with protein for reasons of convenience, lower cost (relative to meat and fish products) and to avoid the concurrent consumption of carbohydrates and fats. In addition, some argue that bodybuilders, by virtue of their unique training and goals, require higher-than-average quantities of protein to support maximal muscle growth; however, there is no compelling evidence and no scientific consensus for bodybuilders to consume more protein than the recommended dietary allowance.
Protein supplements are sold in ready-to-drink shakes, bars, meal replacement products (see below), bites, oats, gels and powders. Protein powders are the most popular and may have flavoring added for palatability. The powder is usually mixed with water, milk or juice and is generally consumed immediately before and after exercising, or in place of a meal. The sources of protein are as follows, and differ in protein quality depending on their amino acid profile and digestibility:

- **Whey protein** contains high levels of all the essential amino acids and branched-chain amino acids. It also has the highest content of the amino acid cysteine, which aids in the biosynthesis of glutathione. For bodybuilders, whey protein provides amino acids used to aid in muscle recovery. Whey protein is derived from the process of making cheese from milk. There are three types of whey protein: whey concentrate, whey isolate, and whey hydrolysate. Whey concentrate is 29–89% protein by weight whereas whey isolate is 90%+ protein by weight. Whey hydrolysate is enzymatically predigested and therefore has the highest rate of digestion of all protein types. Whey protein is usually taken immediately before and after a workout.

- **Casein protein** (or milk protein) has glutamine, and casomorphin. Casein is usually taken before going to bed.

- **Soy protein** from soybeans contain isoflavones, a type of phytoestrogen.

- **Egg-white protein** is a lactose- and dairy-free protein.

- **Hemp protein** from hemp seed contains highly-digestible protein, and hemp oil is high in essential fatty acids.

- **Rice protein**, when made from the whole grain, is a protein source that is highly digestible and allergen free. Since rice protein is low in the amino acid lysine, it is often combined with pea protein powder to achieve a superior amino acid profile.

- **Pea protein** is a hypoallergenic protein with a lighter texture than most other protein powders. Pea protein has an amino acid profile similar to that of soy, but pea protein does not elicit concerns about unknown effects of phytoestrogens. Pea protein is also less allergic than soy. Pea protein has high fiber content and has no allergic ingredients and therefore is easy for digestion as compared to whey protein. Pea protein is a slow digesting protein and is able to keep you full longer.
Some nutritionists claim that osteoporosis may occur from excessive protein intake because protein can put pressure on the kidneys and lead to bone loss due to calcium leaching. However, some have suggested that higher calcium excretion may be due to a corresponding increase in protein-induced calcium absorption in the intestines. In addition to complete proteins, some supplements will contain protein fragments such as branched-chain amino acids or individual amino acids (such as glutamine). Amino acids are considered to be inferior to whole protein and have been used by some companies to artificially inflate and falsify protein values in their product (protein spiking). Many protein supplements explicitly indicate on the label that no protein spiking has occurred.

**Branched-chain amino acids**

Amino acids are the building blocks of protein; the body breaks consumed protein into amino acids in the stomach and intestines. Amino acids are classified as essential, conditionally essential and non-essential. There are three branched-chain amino acids (BCAAs): leucine, isoleucine, and valine. All three branched-chain amino acids are essential amino acids. Each has numerous benefits on various biological processes in the body. Unlike other amino acids, BCAAs are metabolized in the muscle and have an anabolic/anti-catabolic effect on it. There is some evidence that BCAA’s may enhance muscle recovery after intense physical activity and no side effects have been reported at this time.

**Glutamine**

Glutamine is the most abundant amino acid found in human muscle and is commonly found in supplements or as a micronized, instantly soluble powder because supplement manufacturers claim the body’s natural glutamine stores are...
depleted during anaerobic exercise. Some studies have shown there to be no significant effect of glutamine on bench press strength, knee-extension torque or lean muscle mass when compared to controls taking a placebo, though another study found that glutamine is beneficial in raising T-helper/suppressor cell ratio in long-distance runners.

### Essential fatty acids

The [essential fatty acids](alpha-linolenic acid and linoleic acid) may be important to supplement while bodybuilding; these cannot readily be made in the body, but are required for various functions within the body to take place. Fatty fish, such as fresh salmon and trout are rich in essential fatty acids and fish oils can also be taken in supplement form. Flaxseed oil, often sold as a supplement on its own, is an ideal source of alpha-linolenic acid, which can also be found in walnuts and pumpkin seeds.

### Ergogenic Aids

Ergogenic Aids or supplements are substances purposefully taken to improve athletic performance. Not all ergogenic aids or supplements confer such benefits. Below, several substances that have some scientific evidence to support their athletic performance benefit are discussed.

### Creatine

Creatine is an organic acid naturally occurring in the body that supplies energy to muscle cells for short bursts of energy (as required in lifting weights) via creatine phosphate replenishment of ATP. A number of scientific studies have shown that creatine can improve strength, energy, muscle mass, and recovery times. In addition, recent studies have also shown that creatine improves brain function. and reduces mental fatigue. Unlike steroids or other performance-enhancing drugs, creatine can be found naturally in many common foods such as herring, tuna, salmon, and beef.

![Figure 15.6.3: Skeletal formula of creatine](https://med.libretexts.org/Courses/American_Public_University/APUS%3A_An_Introduction_to_Nutrition_(Byerley)/Text/Chapter_15%3A_Nutrition_and_Exercise/15.6%3A_Fitness_Supplements_and_Steroids)

Creatine increases what is known as *cell volumization* by drawing water into muscle cells, making them larger. This [*intracellular* retention should not be confused with the common myth that creatine causes bloating (or *intercellular* water retention). Creatine is sold in a variety of forms, including creatine monohydrate and creatine ethyl ester, amongst others. Though all types of creatine are sold for the same purposes, there are subtle differences between them, such as price and necessary dosage.

In *The New Encyclopedia of Modern Bodybuilding, 2nd ed.*, author Arnold Schwarzenegger states:
Creatine monohydrate is regarded as a necessity by most bodybuilders. Creatine monohydrate is the most cost-effective dietary supplement in terms of muscle size and strength gains. … There is no preferred creatine supplement, but it is believed that creatine works best when it is consumed with simple carbohydrates. This can be accomplished by mixing powdered creatine with grape juice, lemonade, or many high glycemic index drinks.

Some studies have suggested that consumption of creatine with protein and carbohydrates can have a greater effect than creatine combined with either protein or carbohydrates alone.

**β-Hydroxy β-methylbutyrate (HMB)**

HMB is a metabolite of the amino acid leucine and leucines' keto acid, alpha-ketoisocaprate (KIC). It occurs naturally in small amounts in grapefruit, alfalfa, and catfish, and is naturally synthesized in the human body in the liver and muscle, probably in response to protein synthesis. When combined with an appropriate exercise program, dietary supplementation with β-hydroxy β-methylbutyrate (HMB) may augment gains in muscle hypertrophy (i.e., the size of a muscle), muscle strength, and lean body mass, reduce exercise-induced skeletal muscle damage, and expedite recovery from high-intensity exercise; however, there is insufficient scientific evidence to support these claims. HMB is believed to produce these effects by increasing muscle protein synthesis and decreasing muscle protein breakdown by various mechanisms, including activation of the mechanistic target of rapamycin (mTOR) and inhibition of the proteasome in skeletal muscles. The inhibition of exercise-induced skeletal muscle damage by HMB is affected by the time that it is used relative to exercise. The greatest reduction in skeletal muscle damage from a single bout of exercise appears to occur when calcium HMB is ingested 1–2 hours prior to exercise.

**Meal Replacement Products (MRP)**

Meal replacement products (MRPs) are either pre-packaged powdered drink mixes or edible bars designed to replace prepared meals. MRPs are generally high in protein, low in fat, have a low to moderate amount of carbohydrates, and contain a wide array of vitamins and minerals. The majority of MRPs use whey protein, casein (often listed as calcium caseinate or micellar casein), soy protein, and/or egg albumin as protein sources. Carbohydrates are typically derived from maltodextrin, oat fiber, brown rice, and/or wheat flour. Some MRPs also contain flax oil powder as a source of essential fatty acids.

MRPs can also contain other ingredients, such as creatine monohydrate, glutamine peptides, L-glutamine, calcium alpha-ketoglutarate, additional amino acids, lactoferrin, conjugated linoleic acid, and medium-chain triglycerides. A sub-class of MRPs are called 'weight gainers' and have a high ratio of carbohydrate:protein. Where a MRP would have a 0.25-2:1 ratio of carbohydrate:protein a weight gainer would have in the order of between 3-5:1 ratios.

The effect of HMB on skeletal muscle damage has been assessed in studies using four different biomarkers of muscle damage or protein breakdown: serum creatine kinase, serum lactate dehydrogenase, urinary urea nitrogen, and urinary 3-methylhistidine. When exercise intensity and volume are sufficient to cause skeletal muscle damage, such as during long-distance running or progressive overload, HMB supplementation has been demonstrated to attenuate the rise in these biomarkers by 20–60%.
Thermogenic products

A thermogenic is a broad term for any supplement that the manufacturer claims will cause thermogenesis, resulting in increased body temperature, increased metabolic rate, and consequently an increased rate in the burning of body fat and weight loss. Until 2004 almost every product found in this supplement category comprised the "ECA stack": ephedrine, caffeine, and aspirin. However, on February 6, 2004, the Food and Drug Administration (FDA) banned the sale of ephedra and its alkaloid, ephedrine, for use in weight loss formulas. Several manufacturers replaced the ephedra component of the "ECA" stack with bitter orange or citrus aurantium (containing synephrine) instead of the ephedrine.

Caffeine

Caffeine is a chemical called xanthine found in the seeds, leaves, and fruit of many plants, where it acts as a natural pesticide. It is the most widely consumed psychoactive substance and is such an important part of many people’s lives that they might not even think of it as a drug. Up to 90 percent of adults around the world use it on a daily basis. According to both the FDA and the American Medical Association, the moderate use of caffeine is “generally recognized as safe.” It is considered a legal psychoactive drug and, for the most part, is completely unregulated.

Typical Doses and Dietary Sources

What is a “moderate intake” of caffeine? Caffeine intakes are described in the following manner:

- **Low–moderate intake.** 130–300 milligrams per day
- **Moderate intake.** 200–300 milligrams per day
- **High intake.** 400 or more milligrams per day

The average caffeine consumption for American adults is considered moderate at 280 milligrams per day, although it is not uncommon for people to consume up to 600 milligrams per day. This works out to almost 4 ½ cups of coffee per day. The bitter taste of caffeine is palatable for many and coffee is the most readily available source of it, accounting for 70 percent of daily caffeine consumption. The second readily available source of caffeine is soft drinks, delivering 16 percent of daily caffeine. (In this case, the bitter caffeine taste is usually masked by a large amount of added sugar.) Tea is the third common source of caffeine, at 12 percent.

Just how much caffeine is there in a cup of coffee? It varies. The caffeine content of an average cup of coffee can range from 102 to 200 milligrams, and the range of tea is 40 to 120 milligrams. Table 15.6.2 provides useful information on the levels of caffeine found in common beverages. When estimating your total caffeine consumption remember its not only in beverages but also some foods and medicine.

<table>
<thead>
<tr>
<th>Beverage/Food</th>
<th>Milligrams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starbuck’s Grande Coffee (16 oz.)</td>
<td>380</td>
</tr>
<tr>
<td>Plain brewed coffee (8 oz.)</td>
<td>102–200</td>
</tr>
</tbody>
</table>

https://med.libretexts.org/Courses/American_Public_University/APUS%3A_An_Introduction_to_Nutrition_(Byerley)/Text/Chapter
<table>
<thead>
<tr>
<th>Beverage/Food</th>
<th>Milligrams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Espresso (1 oz.)</td>
<td>30–90</td>
</tr>
<tr>
<td>Plain, decaffeinated coffee (8 oz.)</td>
<td>3–12</td>
</tr>
<tr>
<td>Tea, brewed (8 oz.)</td>
<td>40–120</td>
</tr>
<tr>
<td>Green tea (8 oz.)</td>
<td>25–40</td>
</tr>
<tr>
<td>Coca-Cola Classic (12 oz.)</td>
<td>35</td>
</tr>
<tr>
<td>Dr. Pepper (12 oz.)</td>
<td>44</td>
</tr>
<tr>
<td>Jolt Cola (12 oz.)</td>
<td>72</td>
</tr>
<tr>
<td>Mountain Dew (12 oz.)</td>
<td>54</td>
</tr>
<tr>
<td>Mountain Dew, MDX (12 oz.)</td>
<td>71</td>
</tr>
<tr>
<td>Pepsi-Cola (12 oz.)</td>
<td>38</td>
</tr>
<tr>
<td>Red Bull (8.5 oz.)</td>
<td>80</td>
</tr>
<tr>
<td>Full Throttle (16 oz.)</td>
<td>144</td>
</tr>
<tr>
<td>Monster Energy (16 oz.)</td>
<td>160</td>
</tr>
<tr>
<td>Spike Shooter (8.4 oz.)</td>
<td>300</td>
</tr>
</tbody>
</table>


**Health Benefits of Caffeine**

The most renowned effects of caffeine on the body are increased alertness and delay of fatigue and sleep. How does caffeine stimulate the brain? Watch "Video 15.6.1" to see a graphic account of a brain on caffeine. Caffeine is chemically similar to a chemical in our brains (adenosine). Caffeine interacts with adenosine’s specific protein receptor. It blocks the actions of the adenosine, and affects the levels of signaling molecules in the brain, leading to an increase in energy metabolism. At the molecular level, caffeine stimulates the brain, increasing alertness and causing a delay of fatigue and sleep. At high doses caffeine stimulates the motor cortex of the brain and interferes with the sleep-wake cycle, causing side effects such as shakiness, anxiety, and insomnia. People's sensitivity to the adverse effects of caffeine varies and some people develop side effects at much lower doses. The many effects caffeine has on the brain do not diminish with habitual drinking of caffeinated beverages.
Video 15.6.1: A Brain on Caffeine. Watch this graphic account of the brain on caffeine.

Scientific studies suggest caffeine can improve endurance capacity by increasing energy available during exercise. The effect may only work in non-caffeine drinkers and it only takes 1-3 days for the body to become "caffeine-naive."

Bicarbonate

The term bicarbonate refers to sodium bicarbonate a salt that disassociates in water to form sodium and bicarbonate ions. Remember, the small intestine produces and uses bicarbonate to neutralize the acid in your stomach. Baking soda is sodium bicarbonate. There is limited scientific evidence that bicarbonate can improve athletic performance. The mechanism of action is through increased buffering of the blood which may be beneficial for high-intensity exercise.

Growth Hormone

Growth hormone (GH) is a hormone our body produces. In sports, athletes use this the abbreviations GH or HGH (human growth hormone) to refer to growth hormone. GH is a prescription medication so possession and use of it without a prescription is illegal. There is limited scientific evidence that it will increase muscle mass and improve athletic performance. Adverse effects of inappropriately using GH include weakened heart wall and premature death.

Anabolic Steroids

While the use of anabolic steroids is prohibited in sports, there is scientific evidence that anabolic steroids can increase muscle mass and thus improve athletic performance. Anabolic steroids come in both synthetic and natural form so
the athlete must be careful as these compounds can be hidden in foods from unsuspecting athletes. Anabolic steroids mimic the effects seen in adolescents with muscle growth but have adverse effects and in some cases, these effects are irreversible. Side effects include extreme aggression, breathing difficulty, heart disease, blood clots, liver tumors, loss of libido, baldness, testicular atrophy, clitoral enlargement and muscularization in women.

Prohormone

Prohormones are precursors to hormones and are most typically sold to bodybuilders as a precursor to the natural hormone testosterone. This conversion requires naturally occurring enzymes in the body. Side effects are not uncommon, as prohormones can also convert further into DHT and estrogen. To deal with this, many supplements also have aromatase inhibitors and DHT blockers such as chrysin and 4-androstene-3,6,17-trione. To date, most prohormone products have not been thoroughly studied, and the health effects of prolonged use are unknown. Although initially available over the counter, their purchase was made illegal without a prescription in the US in 2004, and they hold similar status in many other countries. They remain legal, however, in the United Kingdom and the wider European Union. Their use is prohibited by most sporting bodies.

Sports Drinks

Scientific studies under certain circumstances show that consuming sports drinks (instead of plain water) during high-intensity exercise lasting longer than one hour significantly enhances endurance, and some evidence indicates it additionally enhances performance. There is no consistent evidence that drinking sports drinks instead of plain water enhance endurance or performance in individuals exercising less than one hour and at low to moderate intensities. A well-concocted sports drink contains sugar, water, and sodium in the correct proportions so that hydration is optimized. The sugar is helpful in maintaining blood-glucose levels needed to fuel muscles, the water keeps an athlete hydrated, and the sodium enhances fluid absorption and replaces some of that lost in sweat. The American College of Sports Medicine states that the goal of drinking fluids during exercise is to prevent dehydration, which compromises performance and endurance.

The primary source of water loss during intense physical activity is sweat. Perspiration rates are variable and dependent on many factors including body composition, humidity, temperature, and type of exercise. The hydration goal for obtaining optimal endurance and performance is to replace what is lost, not to over-hydrate. A person’s sweating rate can be approximated by measuring weight before and after exercise—the difference in weight will be the amount of water weight you lost.

The primary electrolyte lost in sweat is sodium. One liter of sweat can contain between 1,000–2,000 milligrams of sodium. Potassium, magnesium, and calcium are also lost, but in much lower amounts. If you are exercising at high intensity for greater than ninety minutes, it is important to replace sodium as well as water. This can be partly accomplished by consuming a sports drink. The highest content of sodium in commercial sports drinks is approximately 450 milligrams per liter and thus will not replace all lost sodium unless a person drinks several liters. This is NOT recommended, as water intoxication not only compromises performance but may also be deadly. The sodium in sports drinks enhances fluid absorption so that rehydration is more efficiently accomplished. If you are not exercising for more than ninety minutes at a high intensity, dietary intake of sodium and other electrolytes should be sufficient for replacing lost electrolytes.
Who Needs Sports Drinks?

Children and adult athletes exercising for more than one hour at high-intensity (tennis, rowing, rugby, soccer, etc.) may benefit endurance-wise and possibly performance-wise from consuming a sports drink rather than water. However, consuming sports drinks provides no benefit over water to endurance, performance, or exercise recovery for those exercising less than an hour. In fact, as with all other sugary drinks containing few to no nutrients, they are only another source of calories. Drinking sports drinks when you are doing no exercise at all is not recommended.

Sports Drink Alternatives

Instead of a sports drink, you can replenish lost fluids and obtain energy and electrolytes during exercise by drinking plain water and eating a sports bar or snack that contains carbohydrates, protein, and electrolytes. Post exercise, low-fat milk has been scientifically shown to be just as effective as a sports drink as a rehydration beverage and it is more nutrient-dense, containing carbohydrates, protein, and electrolytes, in addition to other vitamins.

Contributors

- Wikipedia