

Examine[®]

Vegetarians & Vegans Supplement Guide



Written By: Michael Hull, & Wyatt Brown

Edited By: Pierre-Alexandre Sicart

Reviewed By: Kamal Patel

Table of Contents

- Introduction
- Combos
- Primary Supplements
- Secondary Supplements
- Promising Supplements
- Unproven Supplements
- Inadvisable Supplements
- FAQ

Introduction

India has the longest tradition of vegetarianism on the planet.^[1] My family has been vegetarian for at least a couple of centuries, and we didn't cook meat in the house when I was a kid. Unsurprisingly, in the ensuing decades, I've thought a lot about vegetarianism, including its health effects and how supplements fit in.

I've also pondered the ethical implications. Some vegetarians oppose any killing of animals, but others oppose only factory farming — because of how animals are treated or just because of the *yuck* factor. Paul McCartney famously said, "If slaughterhouses had glass walls, everyone would be a vegetarian."

My field of expertise is not ethics, however, but nutrition. Of the many reasons people have to be vegetarians,^[2] the one we'll touch on in this introduction is the notion that a plant-based or even plant-only diet is *healthier*.

But wait ...

What exactly are we talking about here?

Do not eat animals

Unlike most other dietary patterns, vegetarianism doesn't require that you track calories or macronutrients or consult a complex list of *yay* and *nay* foods. It has only one rule:

And [veganism](#) just goes one step farther:

Do not eat animal products

Still, a few gray-area foods have been debated. Some vegans eat honey,^[3] for instance, despite its being an animal product (removed from beehives and replaced with [sucrose or high-fructose corn syrup](#)).^[4] And while vegetarians aren't pescetarians — i.e., they don't shun only meat, but also fish — even some vegans eat [bivalves](#) (e.g., clams, oysters, mussels, scallops; which is why they're sometimes called ostrovegans).

Such variations within a "same" dietary pattern can make studies less reliable, especially observational studies. In this introduction, we will discuss veganism as much as vegetarianism, though the latter is more common, because there is less variance between vegan diets than between vegetarian diets, and because veganism is more likely to induce nutrient deficiencies.^[5] Like a healthy vegetarian diet, a healthy vegan diet will be rich in whole foods, with a good balance of complementary nutrients, yet getting enough of all nutrients may prove difficult without the help of some key supplements.

So are vegetarian/vegan diets healthier?

Sometimes

Although vegetarianism has a long history and veganism is quickly growing in popularity, randomized trials on either diet pattern are still few. Vegetarian and vegan diets do show promise for a variety of outcomes, from weight loss^[6] to autoimmunity,^[7] but they are seldom compared to other popular diets.

And the data we do have is quite mixed.

The Adventist study,^[8] one of the largest studies on plant-based diets, and the Epic Oxford study^[9] suggest that vegetarians live a bit longer. Both are observational studies, however, and those tend to be unreliable for several reasons:

- They rely on the participants' memory, even though people often misremember and underestimate what they ate even shortly after eating.^{[10][11][12][13]}
- As aforementioned, not all vegetarian diets are the same.
- There are differences in how strictly different people adhere to their diet of choice.^[14]
- Correlation does not imply causation. People able to stick to a vegetarian diet are more likely to exercise, not smoke, and drink only in moderation,^[8] and each of those factors can, by itself, promote health and prolong life.
- It can be tricky to look at specific health outcomes over time — e.g., [cardiovascular mortality](#) is harder to study now than in earlier decades because, thankfully, the ratio of `_non-fatal_` to `_fatal_` heart attacks is increasing.

There are of course a variety of other important health outcomes, outside death and heart disease — such as cancer. Some animal products, notably red meat, have been associated with an increased [risk of cancer](#). People who regularly consume either processed or charred meat seem more likely to get bowel cancer (aka [colorectal cancer](#)).^[15] And a type of sugar compound called [Neu5gc](#), present only in animal products, has been found in human tumors.^[16]

The evidence is still sparse and mostly in animals, but one meta-analysis of human studies has linked vegetarian diets to less death from [heart disease](#), and both vegetarian and vegan diets to less death from cancer.^[17] It is important to note, however, that the same meta-analysis found that a *healthy* plant-based diet rich in fruits, veggies, and whole grains was linked to less heart disease than was an *unhealthy* plant-based diet rich in sweets and refined grains.

Prioritize whole foods

Like animals — including us humans — plants are composed of cells. As such, eating plants, whether raw or cooked, means consuming their cells and extracellular material, sometimes called their *food matrix*.^[18]

A plant's food matrix may undergo processing ranging from simple heating or mixing to complex extraction, chemical alteration, decoloration, deodorization, and [a plethora of other techniques](#). You may be vaguely aware that your packaged food hails from a factory, but when people see the extent of processing undergone by foods rich in flour, sugar, and inexpensive vegetable oils, they are often astounded.

A diet rich in whole foods is healthier than one rich in processed foods — because it is richer in vitamins and minerals and because it is less likely to lead to obesity. [A 2019 metabolic-ward trial](#) showed that people told to eat as much as they'd like gained significantly more weight when provided with ultra-processed options than with less-processing options.^[19]

One of the main reasons is lesser satiety: an apple is more satiating than applesauce, which is more satiating than apple juice.^[20] Apples contain fiber and water bound up in a food matrix, applesauce breaks down much of that matrix while retaining much of the fiber, and apple juice breaks down all of the matrix and loses all the fiber.

And of course, apple pies introduce novel and hyperpalatable additional flavors and textures such as a

flaky crust, cool and creamy whipped cream or ice cream, and extra sugar mixed in with the apple. Actually, apples are very seldom the main ingredient of apple pies — an apple pie is no more a fruit than pizza is a vegetable.

Try, then try again

There are many hot-button issues around [pesticides in plants](#),^[21] [hormones in meat](#),^[22] and heavy metals and other [toxicants in fish](#).^[23] But while a lot of people have a strong opinion on what the detriments are, nobody really *knows*— we're only *starting* to understand these topics through rigorous research.

There are also unknowns regarding the benefits and drawbacks of vegetarian and vegan diets in general. As we mentioned, studies comparing those to other diets are few. One question in particular needs answering: if the health benefits of vegetarianism and veganism are real and really due to the diet (and not to a correlated factor, such as people who are vegetarians also being people who exercise more), what is the reason? The absence of meat products? Or the abundance of plant products? Or both?

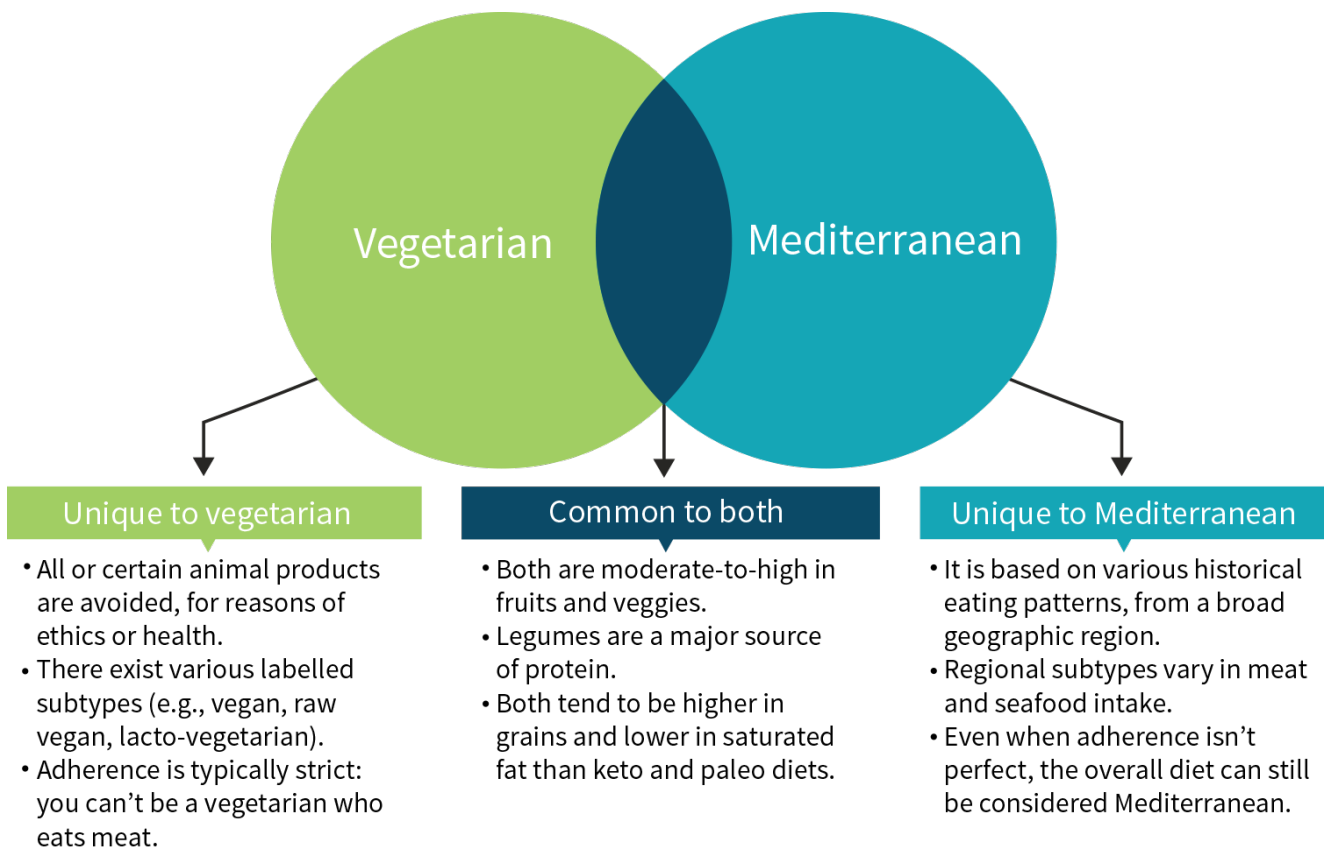
We don't have the answer. There is no denying, however, that animal products contain nutrients that are difficult or even impossible to get from whole plant-based foods (nutrients such as [EPA and DHA](#), found in fish). So it may be that a diet rich in whole plant-based foods with *some* animal products would be healthiest. Or it may be that a purely vegan diet with some vegan supplements (such as EPA and DHA extracted from algae) would be best.

We don't know.

And to complicate things further, while the research tells us what works on average, it also tells us that different diets work differently for different people (e.g., it shows that low-fat diets and low-carb diets perform equally well for weight loss on average, but [not at the individual level](#)).

This is where personal experimentation plays a role: you can test different diets that interest you, based notably on the studies, and see how they affect you, physically as well as mentally (since a diet that makes you miserable is probably not the right diet for you, in the long run). Maybe strict veganism will be your thing. Or maybe you'll feel better on a nonvegetarian yet plant-rich diet, such as the [Mediterranean diet](#).

Comparing plant-heavy diets



Listen to your body

Vegan and vegetarian diets are linked to a higher incidence of certain digestive issues,^[24] probably because of their usually high content in *fiber* and *FODMAPs*.

[Fiber](#) in general can provide a host of health benefits, such as greater satiety, but digestively distressing fibers such as the galactans in lentils can cause a lot of gas to be produced, especially in people who brutally rather than progressively switch to a vegetarian diet.^[25]

[FODMAPs](#) are types of carbohydrates that are easily fermented in your gut (they're *fermentable oligo-, di-, mono-saccharides and polyols*). Over the past two decades, research has linked FODMAPs to *irritable bowel syndrome (IBS)*.^[26]

The best-known FODMAP is [lactose](#). People who don't have adequate amounts of the [lactase enzyme](#) (i.e., a large portion of the world population) [cannot digest lactose](#), but their intestinal flora still can, causing gas, bloating, and potentially diarrhea.

Food FODMAP content

High FODMAP Foods

Asparagus, onions, garlic, legumes/pulses, sugar snap peas, beetroot, celery, sweet corn



Low FODMAP Foods

Bean sprouts, bell peppers, bok choy, carrots, cucumbers, fresh herbs, green beans, lettuce, tomatoes, zucchini

Apples, mangos, nashi pears, nectarines, peaches, pears, plums, watermelons



Bananas, grapes, mandarins, melons, oranges

Cow's milk, cream, custard, ice cream, soft cheeses, yogurt



Hard cheeses, lactose-free milk, lactose-free yogurts

Cereals, rye, wheat-based, wheat-containing bread, wheat pasta



Gluten-free bread, gluten-free pasta, oats, rice quinoa, rice bubbles, sourdough spelt bread

Reference: Monash University. [The Low FODMAP Diet](#). Accessed February 2, 2020

Vegan diets have also been linked to [cognitive deficiencies](#)^[27] and [depression](#),^[28] but studies are sparse. Vegans shun all animal products, though, so if those issues are real, they may derive from nutritional deficiencies, which can be corrected by either incorporating more of certain plant-based foods or taking specific supplements.

The rule of thumb here is to listen to your body, and maybe keep a food diary that records what you eat and how you feel (energized, depressed, clear-headed, muzzy ...). Also, before you switch to a new diet entirely, you may want to try removing some foods from your current diet (e.g., foods rich in FODMAPS) and see how you feel.

Don't rely on "superfoods"

"[Superfood](#)" is a popular buzzword you've probably seen on health blogs, in grocery stores, and from well-meaning friends. And every year, there's a new trending superfood. Whether the latest fad is a rare fruit from the Amazon or a seed that cures every disease known to man, most superfoods build on hype, not evidence of real health benefits.

That isn't to mean that specific foods cannot have specific health benefits — eating [blueberries](#) regularly, for instance, has been shown to improve cognition — but your general health depends more on your eating a variety of fruits and vegetables than on your eating any particular one.

Still, there *are* foods vegetarians and vegans may want to prioritize. Vegan diets are often poor in protein, so protein-rich legumes such as beans and lentils are a must. And ironically, the real superfoods of a vegetarian may be animal-based foods: lacto-ovo-vegetarians can eat dairy products and [eggs](#), which

provide them with protein and some micronutrients that tend to be scarce in nonsupplemented vegan diets (e.g., eggs are rich in [choline](#), and milk in [calcium](#)).

What should you look out for?

There are plenty of thriving vegans out there, as well as plenty of thriving meat-eaters. Your diet is your choice; there is no one diet that will cause or solve all your health issues. Still, different diets do affect different people differently, and trying a different diet is more likely to affect your overall health than trying yet another supplement.

However, if you decide to go vegan or vegetarian, whether for ethical or health reasons, you need to make sure that you still get enough of all the nutrients: all the *essential amino acids* ([EAAs](#)), *essential fatty acids* (EFAs), vitamins, and minerals. In this guide, we'll discuss the nutrients that are hard to obtain through plant-based foods — the nutrients you may want to consider supplementing.




Kamal Patel, Co-founder and Director
MBA, MPH, PhD(c) in Nutrition

Combos

Core Combo

With food, take [vitamin B₁₂](#) (25–400 mcg), [algal oil softgels](#) (650 mg of combined EPA and DHA), [creatine](#) (3–5 g), and [carnitine](#) — either acetyl-L-carnitine (250–500 mg) for neurological benefits or L-carnitine (2 g) for non-neurological benefits.

 **Tip: Try one combo alone for a few weeks**

Taking too many supplements at once may prevent you from determining which ones are truly working. Start with just one of the combos suggested here for a couple of weeks before you consider making any modification, such as adding another supplement, altering a supplement's dosage, or incorporating the supplements from an additional combo.

When adding another supplement to your regimen, be methodical. For example, you may wish to take all the supplements from two combos. Select the combo that you wish to try first and take this for a couple of weeks. Then, add one supplement from the second combo and wait another week to see how it affects you. Continue this process until you've added all the supplements you wish to.

If a supplement appears in two combos you wish to combine, don't stack the doses; instead, combine the ranges. For instance, if the range is 2–4 mg in one combo and 3–6 mg in the other, your new range becomes 2–6 mg. Always start with the lower end of the range — especially in this case, since the reason why one of the ranges has a lower ceiling in one combo may be due to a synergy with another supplement in the same combo. Reading through the full supplement entry may help you decide which dose to aim for, but if you're not sure, lower is usually safer.

Specialized Combos

For vegetarian and vegan athletes

Take [beta-alanine](#) (4–6 g) with the core supplements.

[Acetyl-L-carnitine](#) *might* improve focus when taken 30–45 minutes before exercise.

Consume protein throughout the day (1.0–2.2 grams per kilogram of body weight, so 0.45–1.00 g/lb), with the help of a protein powder if necessary. Consult the [protein](#) entry to set the intake level best suited to your needs.

If your [blood levels of vitamin D](#) (25(OH)D) are adequate or you do not know your levels, 400 IU (10 mcg) of [vitamin D₃](#) per day may help maintain levels in the adequate range. If your 25(OH)D levels are low, 800–2,000 IU (20–50 mcg) of D₃ per day is likely to raise them to an adequate level, at which point 400–1,000 IU (20–25 mcg) per day should suffice for maintenance. In case of full-blown deficiency, a medically

supervised intervention will be needed.

For vegetarians and vegans who want to add more protein to their diet

Consume protein throughout the day (1.0–2.2 grams per kilogram of body weight, so 0.45–1.00 g/lb), with the help of a protein powder if necessary. Consult the [protein](#) entry to set the intake level best suited to your needs.

Whole foods are best, but if you cannot tweak your diet to cover your daily protein needs, add 20 g of a [vegetarian or vegan protein powder](#) to the core supplements. Progressively increase this dose as needed. The greater the dose, the greater the benefit from spreading it over several meals.

For vegetarians and vegans avoiding salt

Take [iodine](#) (75–150 mcg) with the core supplements.

If you consume sea vegetables or iodized salt (either by itself or as an ingredient of processed foods), you probably do not need to supplement iodine.

For vegetarians who don't get enough sun

If your [blood levels of vitamin D](#) (25(OH)D) are adequate or you do not know your levels, 400 IU (10 mcg) of [vitamin D₃](#) per day may help maintain levels in the adequate range. If your 25(OH)D levels are low, 800–2,000 IU (20–50 mcg) of D₃ per day is likely to raise them to an adequate level, at which point 400–1,000 IU (20–25 mcg) per day should suffice for maintenance. In case of full-blown deficiency, a medically supervised intervention will be needed.

Primary Supplements

Carnitine

What makes *carnitine* a primary supplement

Compared with omnivores, vegetarians and [vegans](#) tend to live longer with healthier lifestyles, yet their diets make them more susceptible to low levels of certain beneficial compounds, notably carnitine, [creatine](#), [EPA](#), and [DHA](#).

Carnitine plays a role in [cognition](#),^[29] energy metabolism,^[30] and [cardiovascular health](#).^{[31][32][33]} Though your body can synthesize it out of [lysine](#) and methionine, two amino acids, nearly three-fourths of the carnitine in omnivorous people comes from the meat, fish, eggs, and dairy products they consume.

Selected food sources of carnitine

FOOD	PORTION	MILLIGRAMS (mg)
Beefsteak, cooked	4 oz	56–162
Ground beef, cooked	4 oz	87–99
Whole milk	1 cup	8
Codfish, cooked	4 oz	4–7
Chicken breast, cooked	4 oz	3–5
Ice cream	½ cup	3
Cheddar cheese	2 oz	2
Whole-wheat bread	2 slices	0.2
Asparagus, cooked	½ cup	0.1

Adapted from [Carnitine: Fact Sheet for Health Professionals](#). NIH ODS. Last updated October 10, 2017; accessed October 27, 2019

In vegans and vegetarians, supplementation with L-carnitine can reduce muscular fatigue, whereas supplementation with *acetyl-L-carnitine* (ALCAR) can benefit cognition by improving [blood flow](#) and promoting efficient energy use in brain cells.

Adverse effects are generally rare, but some cases of upset stomachs have been reported. Higher doses of L-carnitine (2 g/day or more) can be converted into the compound trimethylamine, which in some people can give a fishy odor to urine, sweat, or breath.

Carnitine and its derivatives might interact negatively with some pharmaceuticals, including anticoagulants (such as [warfarin](#)/Coumadin and [acenocoumarol](#)/Sintrom). People on [thyroid medication](#) or with [hypothyroidism](#) may also wish to forgo carnitine, as it might depress [thyroid hormone](#) levels.

Summary of L-carnitine's benefits



Protects
neurons

Increases
alertness



L-carnitine



Improves
insulin
sensitivity

Decreases
chronic
fatigue




How to take *carnitine*

For neurological benefits, take *acetyl-L-carnitine* (ALCAR). Start with 250 mg twice a day (i.e., 500 mg/day). Over the course of a week, increase to 500 mg twice a day (i.e., 1 g/day). Taking ALCAR on an empty stomach will result in more potent cognitive benefits. This type of carnitine has a tart taste, but it can be dissolved in tea or coffee and still retain its effects.

For general non-neurological benefits, take 2 grams of *L-carnitine* per day, with carbohydrates if you wish to increase the rate of absorption by the muscles.

Those 2 g of *L-carnitine* can be supplemented through 3 g of *L-carnitine L-tartrate* (LCLT) or *glycine propionyl-L-carnitine* (GPLC), but neither option has proven advantages over regular L-carnitine, both are more expensive, and GPLC also clumps easily in moist environments.

 **Tip: Why don't you recommend brands or specific products?**

For two reasons:

- We don't test physical products. What our researchers do — all day, every day — is analyze peer-reviewed studies on supplements and nutrition.
- We go to great lengths to protect our integrity. As you've probably noticed, we don't sell supplements, or even show ads from supplement companies, even though either option would generate a lot more money than our Supplement Guides ever will — and for a lot less work, too.

If we recommended any brands or specific products, our integrity would be called into question, so ... we can't do it. That being said, in the interest of keeping you safe, we drew [a short list of steps you should take](#) if a product has caught your interest.

Creatine



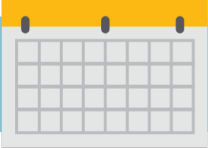





What makes *creatine* a primary supplement

Supplementing with creatine monohydrate increases the body's creatine stores, which are located primarily in the skeletal muscles.^[34] Your cells use creatine to regenerate *adenosine triphosphate (ATP)*,^[34] life's energy currency, before they turn to burning glucose.

Enough creatine is synthesized in the liver, kidney, and pancreas to prevent any deficiency, but additional creatine can improve muscular strength and control, and thus fitness and mobility.^[35] In seniors, these improvements might help reduce the [risk of falls](#), though many more studies are needed for confirmation. When paired with [resistance training](#), creatine may also improve bone health.^{[36][37]} When creatine levels are suboptimal, as is often the case in seniors, [vegans](#), and vegetarians, creatine might also enhance [cognition](#).^[38]

Creatine can be consumed through meat, fish, and eggs, but it can also be supplemented. Decades of research have demonstrated that creatine is generally well tolerated. The only recorded adverse effects are nausea, diarrhea, and stomach cramps in people taking more than 10 grams at once, and even at such high doses, these effects are rare.^[39] Still, should you find yourself particularly sensitive to creatine's digestive adverse effects, split your daily dose, take it with some food, and drink more fluids. You could also try [_micronized _creatine monohydrate](#), which dissolves more easily in liquids.

Evidence for cognitive benefits in vegans and vegetarians

Benton et al. 2011	Rae et al. 2003
<p>Vegans and Vegetarians</p> <p>70  MALE & FEMALE</p>	<p>Vegans and Vegetarians</p> <p>45  MALE & FEMALE</p>
<p>5  DAYS</p>	<p>18  WEEKS</p>
<p>CREATINE PILL</p> <p>5g  PER DAY</p>	<p>CREATINE PILL</p> <p>5g  PER DAY</p>
<p>Improved memory recall Faster reaction time</p> 	<p>Increased recognition memory Reduced mental fatigue</p> 

Omega-3 Fatty Acids

What makes *omega-3 fatty acids* a primary supplement

Essential fatty acids (EFAs) are polyunsaturated fatty acids your body needs and cannot produce. There

are only two kinds of EFAs: linoleic acid (LA) and alpha-linolenic acid (ALA). Neither is very active, so your body transforms the former into notably arachidonic acid (AA) and the latter into eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). LA and AA are omega-6 fatty acids, whereas ALA, EPA, and DHA are omega-3 fatty acids.

LA and ALA compete for the same enzymes for their conversion. Too much LA means that too little ALA gets converted, and vice versa. The LA:ALA ratio in American diets is even higher for vegetarians (10–16:1) and [vegans](#) (14–20:1) than for omnivores (<10:1). Vegetarians and vegans should aim for a 2–4:1 ratio. A ratio lower than 1:1 should be avoided, since it could lead to insufficient conversion of LA to AA.

Most people could achieve a better LA:ALA ratio by increasing their intake of foods rich in ALA (including oils) and decreasing their intake of processed foods rich in LA (notably oils and snacks). A source rich in ALA can also be rich in LA, so take into account the ratio between both types of EFAs.

Plant sources of EFAs*

OIL	LA%	ALA%	LA:ALA RATIO
Flaxseed	14	53	0.3:1
Canola	19	9	2:1
Hempseed	56	18	3:1
Walnut	53	10	5:1
Soybean	51	7	8:1
Corn	54	1	46:1
Safflower	13	0.1	133:1
Cottonseed	52	0.2	258:1
Grapeseed	70	0.1	696:1
Sunflower (mid-oleic)	29	0.04	782:1

* For details on more foods, consult the [USDA FoodData Central Database](#).

Even in an optimal scenario, though, conversion of ALA into EPA and DHA is very inefficient, so consuming EPA and DHA directly can have numerous health benefits. Omnivores need only eat fatty fish, but vegetarians and vegans will need to rely on algal oil softgels (algae being low in fat, eating them directly will not help much). Vegetarians who eat eggs can also get some DHA this way.

Omega-3 fatty acids have blood-thinning properties and so may potentiate other blood thinners (such as [warfarin/Coumadin](#) and [acenocoumarol/Sintrom](#)). They may also lower [blood pressure](#) and increase fasting [blood sugar](#) levels.

How to take *omega-3 fatty acids*

Every day, take 650 mg of combined EPA and DHA in the form of algal oil softgels. If for some reason this is not an option, take 2–4 g of ALA through foods or oils.

Omega-3 oils should be stored in the dark. Softgels can be kept at room temperature, but opened oil bottles should be placed in a cool location (such as the refrigerator). Do not heat omega-3 oils.

Digging Deeper: Oxidized fish oil

Fish oil can go rancid and oxidize when exposed to oxygen, heat, or light. These oils are particularly susceptible to oxidation because of their very-long-chain polyunsaturated fatty acids. The oxidation level is measured using three values.

1. Peroxide value (PV)
2. Anisidine value (AV)
3. Total oxidation value (TOTOX)

The PV is a measure of primary oxidation products (peroxides) and AV a measure of secondary oxidation (aldehydes and ketones). The TOTOX value is calculated using the formula $AV + 2PV$. The lower the TOTOX value, the better the oil quality will be. The Global Organization for EPA and DHA Omega-3 recommends a TOTOX value of no more than 26.^[40]

Oxidation of fish oils may be more common than you suspect. One 2015 study found that nearly 50% of commercial fish oils exceeded the maximum recommended TOTOX value.^[41] while others have found good compliance with TOTOX limits.^{[42][43]} Taken together, the divergent results demonstrate just how widely the quality of commercially available fish oil supplements can be.

Evidence for the health effects of consuming oxidized fish oils is a bit mixed though. For healthy individuals, it would appear that there is a lack of obvious short-term health damage from consuming oxidized fish oil. One study showed no difference in circulating levels of oxidized LDL or inflammatory markers after seven weeks of oxidized fish oil supplementation.^[44]

However, in people with high levels of [cholesterol](#) and [triglycerides](#), consumption of highly oxidized fish oils can minimize its efficiency at improving metabolic markers like fasting [glucose](#), total cholesterol, and triglycerides.^[45]

Vitamin B₁₂ (cobalamins)

What makes *vitamin B₁₂* a primary supplement

Vitamin B₁₂ (cobalamin) deficiency can cause [cognitive impairment](#), [mood](#) disorders, [anemia](#), nerve damage, and other health problems.^[46] B₁₂ can be found in animal products and some fortified foods. The B₁₂ naturally present in food is bound to protein and gets harder to digest as you get older.^[47] Moreover, vegetarians and [vegans](#) are at higher risk of not consuming enough B₁₂.^{[48][49]}

B₁₂ supplementation is recommended for *vegans* because natural sources of B₁₂ are almost all animal-based. *Vegetarians* who regularly consume eggs or dairy products may not need to supplement B₁₂.

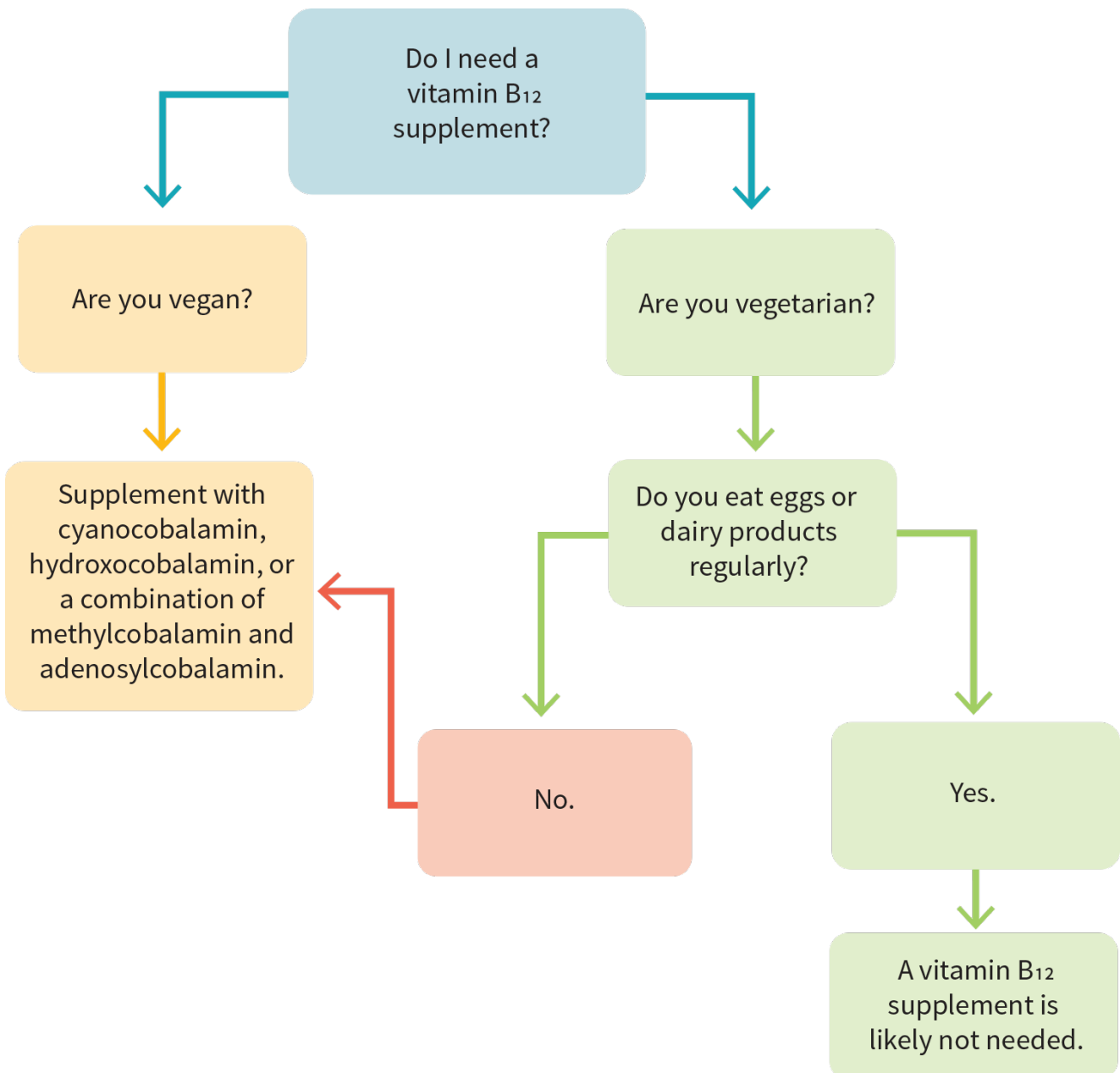
Each vitamin has different forms, called vitamers. Four B₁₂ vitamers can be found in food.

- *Hydroxocobalamin*
- *Aquacobalamin*
- *Methylcobalamin*
- *Adenosylcobalamin*

Most supplements and fortified foods use the synthetic *cyanocobalamin*, which has the advantage of being particularly stable, as long as it is kept away from bright light — *ultraviolet* (UV) rays in particular.^[50]

People with [diabetic nephropathy](#) or [kidney diseases](#) related to diabetes should talk to their physician before supplementing B₁₂.

Vitamin B~12~ Decision Flow Chart



Most vegetarians and vegans will find *25–100 mcg/day* to be enough, while people over fifty or taking [metformin](#) could benefit from *100–400 mcg/day*. Your body will not absorb more than it needs: dosages as high as *5,000 mcg/day* (*5 mg/day*) have not been found to be toxic.

How to take *vitamin B12*

All four commonly supplemented B₁₂ vitamers can degrade when exposed to UV rays,^[50] but *cyanocobalamin* and *hydroxocobalamin* are more stable (and widely available) than *methylcobalamin* and *adenosylcobalamin*.

Methylcobalamin and *adenosylcobalamin* can affect your body directly: they are *bioactive*. The other B₁₂ vitamers are not bioactive, but your body can transform them into *methylcobalamin*, which can be transformed into *adenosylcobalamin*. *Adenosylcobalamin* cannot be transformed into *methylcobalamin*, though, which is why it is seldom taken alone (it is usually paired with *methylcobalamin*).

Take 25–400 mcg/day (all forms included). Most vegetarians and vegans will find 25–100 mcg/day to be enough. People on metformin, over fifty, or with absorption issues should aim toward the higher end of the range (250–400 mcg/day). People with swallowing difficulties or intestinal absorption issues can use sublingual B₁₂ supplements.

Fortunately, your body will not readily absorb more than it needs: doses as high as 1,000 mcg (1 mg) taken daily for 5 years have not been found to produce adverse effects.^[51] For that reason, even the Institute of Medicine (now known as the Health and Medicine Division) did not set a Tolerable Upper Intake Level (UL) for B₁₂.^[52]

Recommended Dietary Allowance (RDA) for vitamin B₁₂ (mcg)

AGE	MALE	FEMALE	PREGNANT	LACTATING
0–6 months	0.4*	0.4*	—	—
7–12 months	0.5*	0.5*	—	—
1–3 years	0.9	0.9	—	—
4–8 years	1.2	1.2	—	—
9–13 years	1.8	1.8	—	—
>13 years	2.4	2.4	2.6	2.8

* Adequate Intake (AI)

Reference: Institute of Medicine. [Vitamin B₁₂](#) (chapter 9 in *Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B₆, Folate, Vitamin B₁₂, Pantothenic Acid, Biotin, and Choline*). The National Academies Press. 1998. DOI:[10.17226/6015](https://doi.org/10.17226/6015)

Secondary Supplements

Iodine

What makes *iodine* a secondary option

Iodine is a dietary mineral important for cognitive development in children and a properly functioning thyroid in all age groups. Too little or too much iodine can cause a decrease in [thyroid hormone](#) production, or even a [goiter](#) — an enlargement of the thyroid glands visible as a swelling of the front of the neck. Iodine can also counteract the decrease in thyroid hormone production caused by the goitrogens present in cruciferous vegetables (broccoli, kale ...).

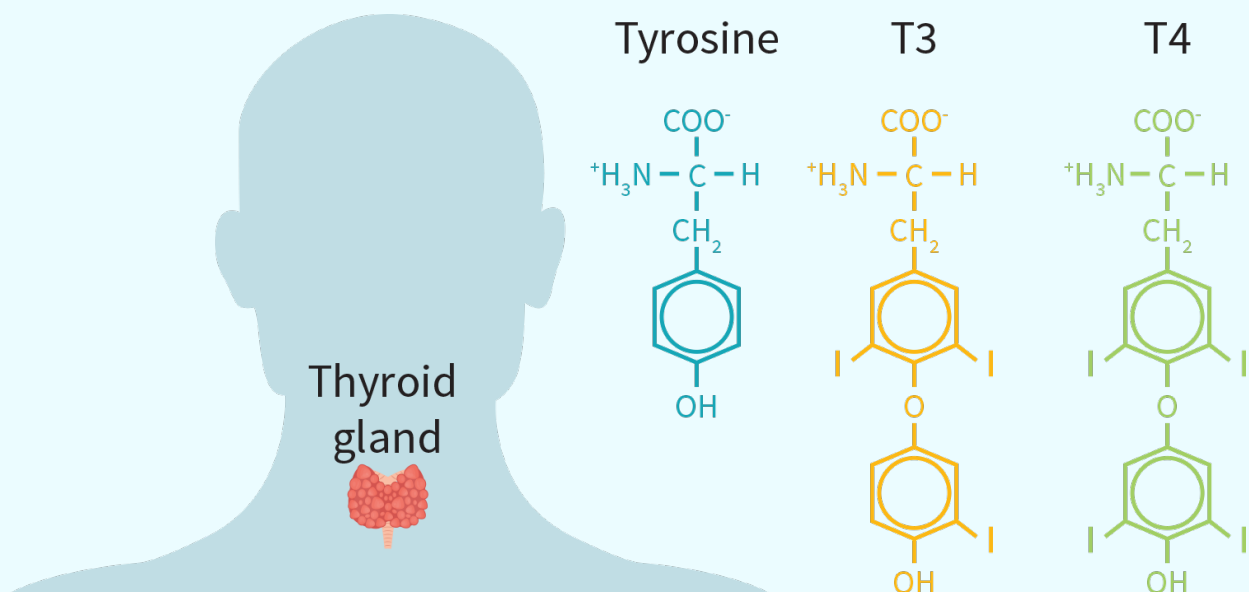
Digging Deeper: Thyroid Hormones 101

The thyroid gland makes two major kinds of thyroid hormones: T3 and T4, which are shown in the figure below. These hormones are synthesized from the amino acid tyrosine and iodine. T3 had three iodines stuck onto it, whereas T4 had four.

The thyroid gland makes mostly T4. However, T3 is much more potent, but T4 tends to last for a longer time in the blood. Tissues throughout the body take up T4 and convert it to the more potent T3, which leads to lots of metabolic changes throughout the body, depending on the tissue.

Thyroid hormones regulate a lot of different processes, including metabolic rate, tissue growth and maintenance.

The thyroid gland and thyroid hormones



Females who plan to have children in the near future should keep an eye on their iodine intake, since iodine is important for fetal development.

Iodine is stored in body tissues, so a little can be found in animal products, but the main dietary sources are sea vegetables and iodized salt (in some countries, notably the United States, table salt is iodized by default). Iodine is a secondary supplement in this guide because many vegetarians) and [vegans](#) avoid table salt and processed foods (some of which contain iodized salt). If this is not the case with you, or if you frequently eat sea vegetables such as seaweeds, you probably do not need to supplement iodine.

How to take *iodine*

Take 75–150 mcg of iodine once a day, on an empty stomach or with food. Never take more than 500 mcg, unless so advised by your physician. In case of ferropenic anemia (iron deficiency anemia), adding iron-vitamin-c[iron] to iodine can help address low thyroid hormone production.

Recommended Dietary Allowance (RDA) for iodine (mcg)

AGE	MALE	FEMALE	PREGNANT	LACTATING
0–6 months	110*	110*	—	—
7–12 months	130*	130*	—	—
1–3 years	90	90	—	—
4–8 years	90	90	—	—
9–13 years	120	120	—	—
14–18 years	150	150	220	290
>18 years	150	150	220	290

* Adequate intake (AI)

Reference: Institute of Medicine. [Iodine](#) (chapter 8 in *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc*. The National Academies Press. 2001. DOI:[10.17226/10026](#))

The iodine content of seaweeds [varies greatly](#), even within a same species, from less than 100 mcg/g to more than 8,000 mcg/g — a highly unsafe amount. Do not regularly consume high amounts of iodine-rich sea vegetables, such as paddle weed, oarweed, or kelp/kombu. Likewise, high amounts of iodine-rich sea vegetables in supplemental form should be avoided.

Regular consumption of seaweed (no more than three grams per week) or iodized salt (at least 1.5 g/day) should be sufficient to ensure adequate iodine intake.^[53] The use of iodized salt will better ensure sufficient iodine intake.

Iron with Vitamin C

What makes *iron with vitamin C* a secondary

option

Like iodine, iron is a dietary mineral. It associates with proteins and enzymes to support many biological functions, such as energy production and DNA synthesis. Iron gets stored mostly in red blood cells, where it participates in oxygen transport.

Dietary iron exists as heme iron and non-heme iron. Plants, eggs, and dairy products only contain non-heme iron, as do nearly all iron-fortified foods. Not only is this form less bioavailable, its absorption rate is further reduced by a variety of compounds in food, particularly carbonates, fibers, oxalates, phytates, phosphates, and polyphenols. The polyphenols known as tannins (found notably in tea and coffee) are especially potent in that respect.

Of the few compounds known to _enhance _the absorption of non-heme iron, ascorbic acid (vitamin C) works best. However, while concomitant supplementation of iron and vitamin C strongly enhances the absorption of the former, simply adding vitamin C to one's diet barely improves one's iron status.

Since, compared to omnivores, vegetarians and [vegans](#) get little to no heme iron, they are more likely to suffer from iron deficiency. Because of monthly blood loss, premenopausal females are especially at risk — as are frequent blood donors.

It is important to remember, however, that while iron deficiencies are not rare, neither is iron poisoning (especially in children young enough to confuse iron tablets with candies). Without blood loss, there is hardly any iron loss, and while most people do not absorb more iron than they need (within certain limits).

Postmenopausal females need *less* iron (8 mg/day, like males) than premenopausal females (18 mg/day). Although iron deficiency contributes substantially to the high prevalence of [anemia](#) seen in the elderly,^{[54][55]} taking an iron supplement “just in case” (or because you look pale and feel tired) is ill-advised. If you think you might suffer from iron deficiency, see a physician and get tested.

⚠ **Caution: Iron overload**

Too much iron has been linked, via prospective observational studies, to a wide variety of conditions, such as Alzheimer's, heart disease, and colorectal cancer.^{[56][57][58]} There are a couple of groups who don't have to worry as much about iron overload though: menstruating females and vegetarians/vegans (although these groups should still take stock of their iron intake from supplements and diet before adding an iron supplement.).

But for others, especially those who regularly eat red meat, it doesn't take much to push yourself into excess iron territory. And for the nearly one million Americans who have hereditary genetic disorder [hemochromatosis](#), a condition — which typically emerges in adulthood — where you absorb too much dietary iron, the risk is much more serious. Iron buildup can lead to dysfunction in your heart, liver, and pancreas. In extreme cases, it can cause arrhythmias, heart failure, and death.

Those at risk for iron overload should also learn more about how to cook with cast iron safely. We provide full details on how to do so [here](#).

Chances of iron overload in different populations

MOST LIKELY



Individuals with
Hereditary Hemochromatosis

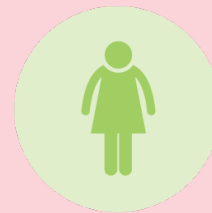
MORE LIKELY



Frequent Red
Meat Eaters



Men



Postmenopausal
Women

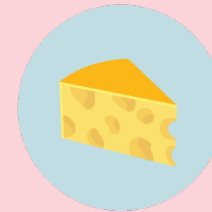
LESS LIKELY



Menstruating
Women



Vegans



Vegetarians

How to take *iron with vitamin C*

Females can supplement up to 18 mg of *iron*, except during pregnancy (27 mg) and after menopause (8 mg). Males should not supplement more than 8 mg.

Children and teenagers should not supplement iron without first consulting a physician.

Recommended Dietary Allowance (RDA) for iron (mg)

AGE	MALE	FEMALE	PREGNANT	LACTATING
-----	------	--------	----------	-----------

AGE	MALE	FEMALE	PREGNANT	LACTATING
0–6 months	0.27*	0.27*	—	—
7–12 months	11	11	—	—
1–3 years	7	7	—	—
4–8 years	10	10	—	—
9–13 years	8	8	—	—
14–18 years	11	15	27	10
19–50 years	8	18	27	9
>50 years	8	7	—	—

* Adequate intake (AI)

Reference: Institute of Medicine. [Iron](#) (chapter 9 in *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc*. The National Academies Press. 2001.

DOI:[10.17226/10026](#))

To facilitate absorption, take your iron dose with 250 mg of *vitamin C* (preferably on an empty stomach, except in case of gastrointestinal symptoms such as nausea, diarrhea, or constipation).

The Recommended Dietary Allowance (RDA) for vitamin C for adults ranges from 75–120 mg per day.^[59] While 250 mg/day dose discussed here exceeds that, it is still well under vitamin C's Tolerable Upper Intake Level (UL) of 2,000 mg/day.

Tolerable Upper Intake Level (UL) for vitamin C (mg)

AGE	MALE	FEMALE	PREGNANT	LACTATING
0–12 months	*	*	—	—
1–3 years	400	400	—	—
4–8 years	650	650	—	—
9–13 years	1,200	1,200	—	—
14–18 years	1,800	1,800	1,800	1,800
>18 years	2,000	2,000	2,000	2,000

* Formula and food should be the only sources of vitamin C for infants.

Reference: Institute of Medicine. [Vitamin C](#) (chapter 5 in *Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids*. The National Academies Press. 2000. DOI:[10.17226/9810](#))

Since [calcium](#), iron, [magnesium](#), and [zinc](#) compete for absorption, it is better to take them at least one hour apart. Iron may also impair the absorption of antibiotics — notably in the [tetracycline class](#) (e.g., doxycycline) and [quinolone class](#) (e.g., ciprofloxacin) — and of drugs used to treat [osteoporosis](#), [hypothyroidism](#), and symptoms of [Parkinson's disease](#); so take iron and pharmaceuticals at least 6 hours apart.

Protein

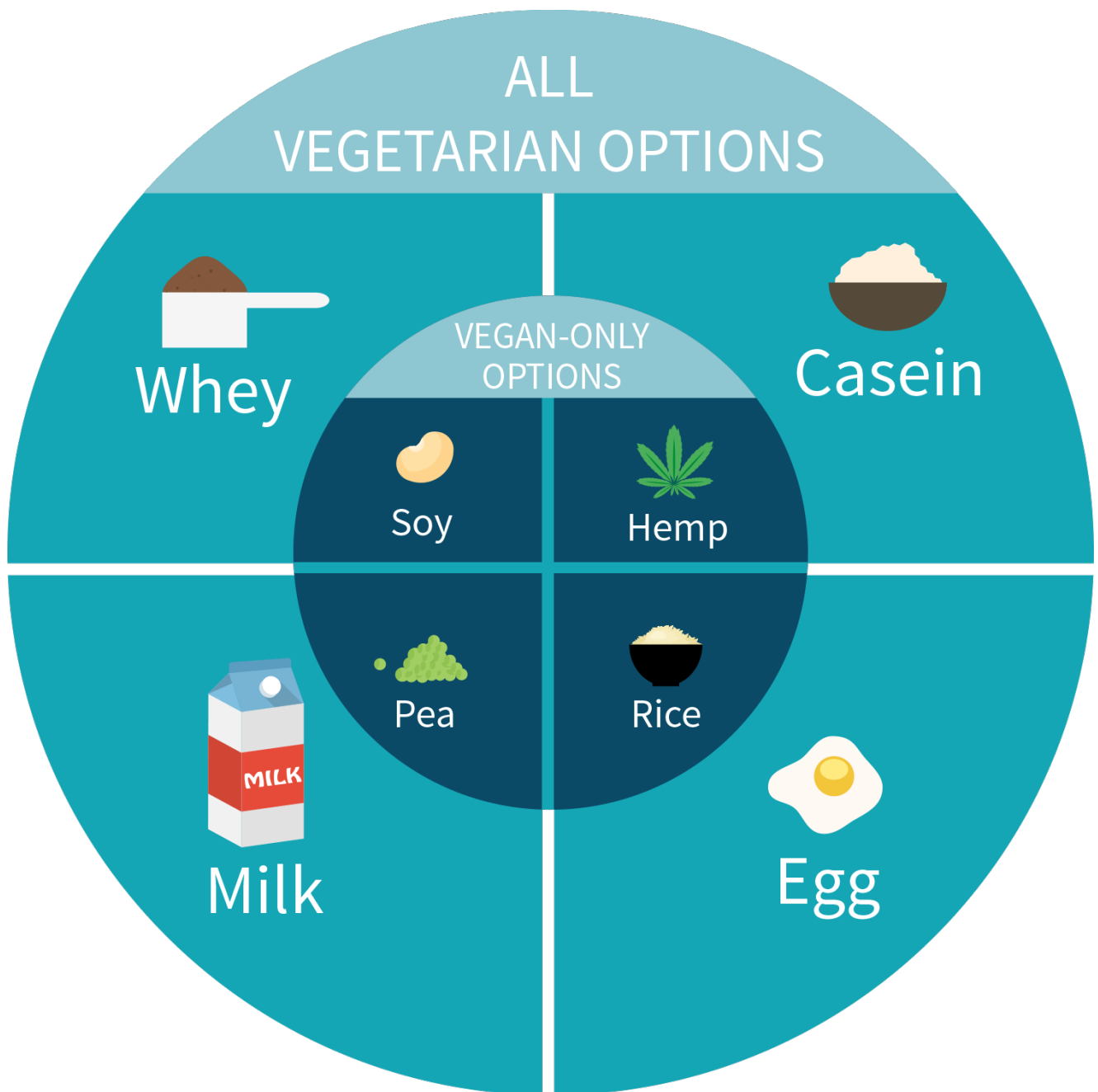
What makes *protein* a secondary option

Dietary protein (the protein you ingest) plays important roles in your body, notably as a provider of *essential amino acids* (EAAs), the amino acids your body needs but cannot synthesize. Unlike most animal proteins, most plant proteins are incomplete (they are poor in one or more EAAs). Moreover, compared to animal proteins, plant proteins tend to be less bioavailable (less protein is absorbed by the body). Vegetarians and [vegans](#) should pay particular attention to their protein intake, with an eye to both quantity and variety. Compared to omnivores, they are more likely to benefit from a supplement, preferably a powder.

[Whey protein](#) and [casein](#) powders are both derived from [milk protein](#) (which is 20% whey and 80% casein). If you are neither lactose intolerant nor vegan, look for a [whey protein concentrate](#) that is at least 80% protein. A little lower is fine if the powder is flavored (any flavoring will use a percentage of the powder), but any big discrepancy should steer you away. Whey protein is cheap and very anabolic (good for building muscle). Micellar casein is more expensive but more anti-catabolic (good for preserving muscle). Since micellar casein digests slowly, it is often seen as the ideal protein to consume before sleep, though some evidence suggests that bedtime protein may not provide any additional benefit if enough protein is consumed during the day.^[60]

But what if you *are* lactose intolerant or vegan? Fortunately, you can still supplement protein powders. Whey protein isolates contain very little lactose. For vegans, two popular options are [soy protein](#), which is a complete protein, and a 70:30 pea:rice protein blend, which is seen as the vegan alternative to whey protein due to their similar amino acid profiles.

Vegetarian- and Vegan-Friendly Protein Sources



[Hemp protein](#) is not a complete protein. Moreover, hemp protein powders are about half protein, the rest being mostly fiber and fat (18% [ALA](#)). As a protein supplement, hemp ranks below the options listed above.

Two-thirds of [spirulina](#) is protein. Like hemp protein, however, spirulina protein is not complete. Furthermore, in high doses (25+ g), spirulina can be very active in the body, in ways that are still uncertain. Therefore, it should not serve as a mainstay protein supplement.

Overall, whole foods are the healthier choice, but if your food intake does not cover your daily protein needs, you could add a supplement (preferably a powder, since the protein-to-calorie ratio of powders tends to be higher than that of other protein supplements, such as protein bars).

How to take *protein*

In the United States, the Recommended Dietary Allowance ([RDA](#)) of 0.8 grams per kilogram of body weight (0.36 g/lb) is considered the minimum amount of protein a healthy adult must consume daily to prevent

muscle wasting when total caloric intake is sufficient.^[61]

The current evidence suggests, however, that this amount has been underestimated. Recent studies point to 1.0–1.2 g/kg as the minimum daily intake before the body starts downregulating important non-essential processes, from immune function to muscle protein synthesis.^{[62][63][64]} Even a reanalysis of the data used to establish the above RDA suggests the minimum daily intake should be at least 1.0 g/kg.^[65]

So, how much protein do you need daily? Here's a quick rundown of how much protein you may need in different situations. If you're *vegan or obtain most of your protein from plants*, then your protein requirements may be on the mid to higher end of the below ranges because plant-based proteins are usually inferior to animal-based proteins with regard to both [bioavailability and amino acid profile](#).

If you want to know more, check out our [in-depth article on protein needs](#).

- If you're *sedentary*, aim for at least 1.2 g/kg (0.54 g/lb). Keep in mind that your body composition will improve more if you add consistent activity, especially resistance training, than if you merely hit a protein target.
- If you're of *healthy weight, active, and wish to keep your weight*, aim for 1.4–1.6 g/kg (0.64–0.73 g/lb). People who are trying to keep the same weight but improve their body composition (more muscle, less fat) may benefit from the higher end of the range.
- If you're of *healthy weight, active, and wish to build muscle*, aim for 1.4–2.4 g/kg (0.64–1.09 g/lb). If you're an experienced lifter in a bulking phase, intakes of up to 3.3 g/kg (1.50 g/lb) may help you minimize fat gain.
- If you're of *healthy weight, active, and wish to lose fat*, aim for 1.8–2.7 g/kg (0.82–1.23 g/lb), skewing toward the higher end of this range as you become leaner or if you increase your caloric deficit (by eating less or exercising more).
- If you're *overweight or obese*, aim for 1.2–1.5 g/kg (0.54–0.68 g/lb). This range, like all the others in this list, is based on your *total* body weight (most studies on people who are overweight or obese report their findings based on total body weight, but you'll find some calculators that determine your optimal protein intake based on your lean mass or your *ideal* body weight).
- If you're *pregnant*, aim for 1.66–1.77 g/kg (0.75–0.80 g/lb).
- If you're *lactating*, aim for at least 1.5 g/kg (0.68 g/lb).

Daily protein intake

BODY WEIGHT	BODY WEIGHT	0.36	0.45	0.54	0.68	0.82	0.91	1.00	g/lb
LBS	KGS	0.8	1.0	1.2	1.5	1.8	2.0	2.2	g/kg
100	45	36	45	54	68	81	91	100	g
125	57	45	57	68	85	103	113	125	g
150	68	54	68	82	102	122	136	150	g
175	79	64	79	95	119	142	159	175	g
200	91	73	91	109	136	164	181	200	g
225	102	82	102	122	153	184	204	225	g
250	113	91	113	136	170	203	227	250	g
275	125	100	125	150	187	225	249	275	g

References: Schoenfeld and Aragon. *J Int Soc Sports Nutr.* 2018.^[66] ● Jäger et al. *J Int Soc Sports Nutr.* 2017.^[67] ● Thomas et al. *Med Sci Sports Exerc.* 2016.^[68] ● Institute of Medicine. [Protein and Amino Acids](#) (chapter 10 in *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids*. The National Academies Press. 2005. DOI:[10.17226/10490](#))

Unless you have a [pre-existing condition](#) that affects your liver or kidneys, the intakes in the above table will not harm these organs.^[69]

For maximal MPS stimulation, [the minimal per-meal dose](#) of [quality protein](#) (such as can be found in meat, eggs, dairy products, and soy) is 0.24–0.40 g/kg for adults in their twenties^{[70][71]} and 0.40–0.60 g/kg for adults aged sixty and older.^[70] Spreading your protein intake over a few meals, making sure this 0.40–0.60 g/kg threshold is met with each meal, will generally result in greater lean mass and strength.

Note that you don't need to calculate your intake so that it falls within the 0.40–0.60 g/kg range. This range isn't an ideal range — it is a range representing individual variations. In other words, some people can reach maximal MPS with just 0.40 g/kg, while others will need as much as 0.60 g/kg. Moreover, higher doses will not be wasted and are probably necessary when eating mixed meals that contain a variety of protein sources. You may have heard that if you eat more than 30 grams of protein in one sitting, the “excess” will pass undigested, but that's just a myth.

Desirable minimal protein intake range* per meal (g), by age for adults

BODY WEIGHT (lbs)	BODY WEIGHT (kgs)	20s	30s, 40s, 50s	≥60
100	45	11–18	13–24	18–27
125	57	14–23	17–30	23–34
175	79	19–32	23–43	32–48
200	91	22–36	27–48	36–54
225	102	24–41	30–54	41–61
250	113	27–45	33–60	45–68
275	125	30–50	37–67	50–75

* The ranges in this table represent individual variations. The minimum protein requirements increase as you age, but to what degree is uncertain because of the age gap left by the studies: most subjects were in their 20s (0.24–0.40 g/kg) or 60s/70s (0.40–0.60 g/kg). For people in their 30s, 40s, or 50s, the 0.29–0.53 g/kg range reflected in this table is an educated guess.

References: Schoenfeld and Aragon. *J Int Soc Sports Nutr.* 2018.^[66] ● Rafii et al. *J Nutr.* 2016.^[63] ● Morton et al. *Front Physiol.* 2015.^[71] ● Moore et al. *J Gerontol A Biol Sci Med Sci.* 2015.^[70] ● Rafii et al. *J Nutr.* 2015.^[62]

Your mileage may vary. The ranges in the paragraphs and table above cover the known extent of interindividual variations among healthy adults.

After exercising, when your muscles are more sensitive to the anabolic effect of protein, take a dose in the range of your “desirable minimal protein intake per meal” (as shown in the table above). If you've been exercising on an empty stomach, you'll be in negative protein balance, so take this dose as soon as possible. Otherwise, try to take it within a couple of hours — the exact size of your “window of opportunity” depends on how much protein you're still digesting.^[72]

Tip: Use our [Protein Intake Calculator](#)

Your protein needs hinge on many factors — notably your weight, health goals, and level of physical activity. Based on our research and the data you input, we can calculate your optimal daily protein intake. Click on the image below to get started!

**YOUR OPTIMAL
PROTEIN INTAKE:
???**

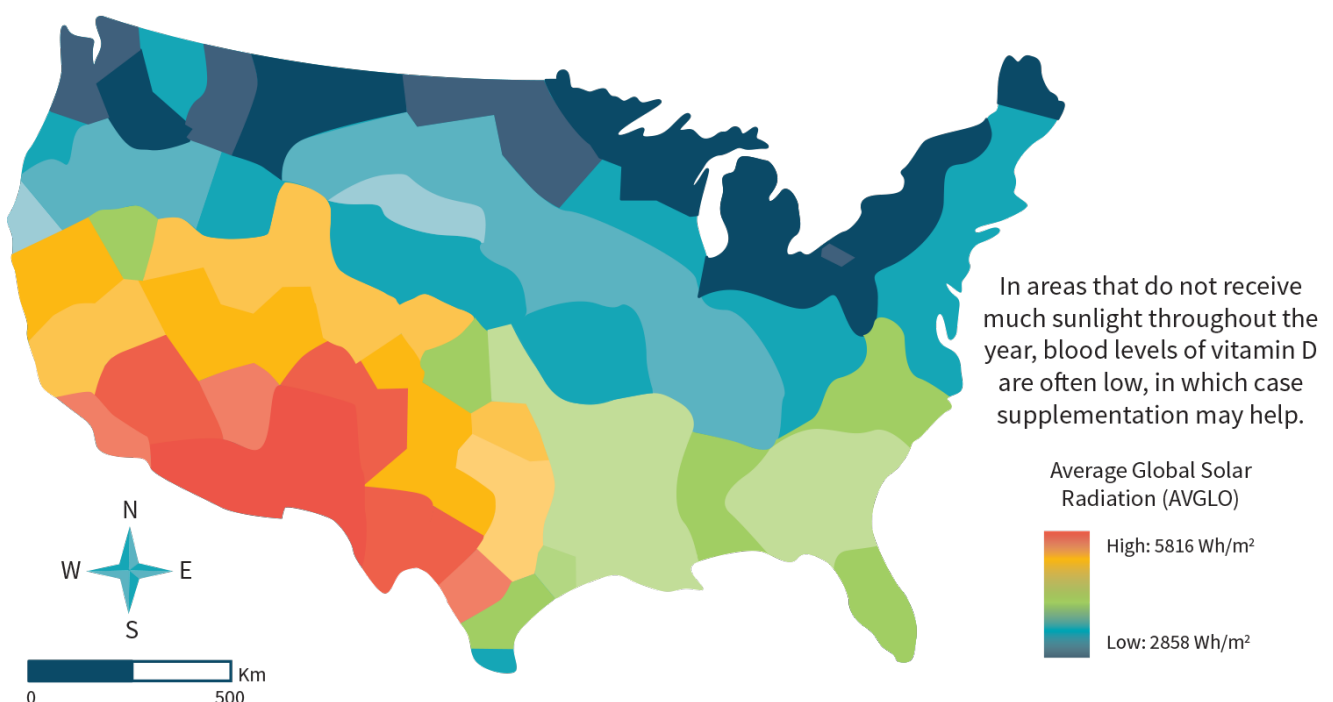
Vitamin D

What makes *vitamin D* a secondary option

Suboptimal levels of vitamin D are common, especially in people whose skin exposure to sunlight (meaning without protection from clothes or sunscreen) is limited. Moreover, the darker your skin, the longer you need to expose yourself to sunlight to synthesize enough vitamin D, which is why people with darker skin are at an increased risk of suboptimal vitamin D levels.^[73]

The situation doesn't improve as you age. The older you get, the less efficient your body becomes at synthesizing vitamin D, the less time you're likely to spend outside, the less vitamin D you're likely to get through food, and the more likely you become to carry extra fat (belly fat has been linked to vitamin D deficiency).^{[74][75]}

Average yearly sunlight exposure in the US



Vitamin D is commonly available in two forms: ergocalciferol (D₂) and cholecalciferol (D₃).

D₂ is available in a handful of plants and fungi, whose D₂ content can be increased dramatically when exposed to *ultraviolet B* (UVB) radiation.^{[76][77]} This is how some commercially available mushrooms contain D₂. Soy milk is often fortified with D₂, as well as with calcium. And of course, D₂ is available in supplement form.

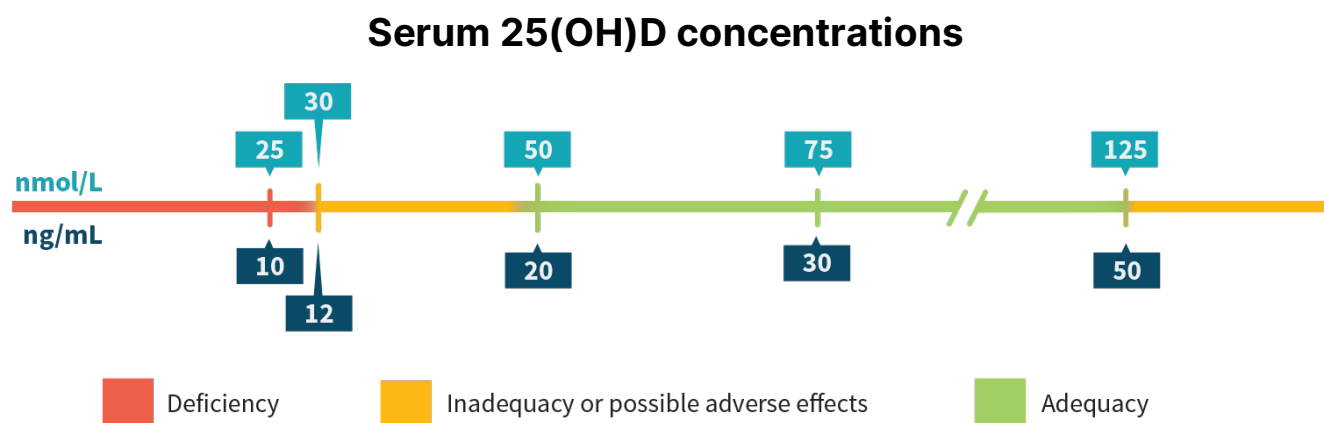
Alas, D₂ is not as bioavailable as D₃, which means your body cannot use it as readily. Moreover, D₂ is not as stable as D₃; it is more likely to degrade with time and variations in temperature and humidity.

D₃ is the kind of vitamin D your body synthesizes from the cholesterol in your skin under the action of the sun's ultraviolet B rays (UVB).^{[78][79][80]} As a supplement, it is usually derived from lanolin^[81], a waxy substance secreted by the skin glands of woolly animals. Sheep are sheared, then the lanolin coating is squeezed off the wool. Since the sheep are not killed in the process, this source of D₃ will be acceptable to some vegetarians. For [vegans](#), D₃ taken from a lichen extract is a vegan-friendly option.

Before turning to supplementation, you should try incorporating some [foods rich in vitamin D](#) into your diet. Very few foods, alas, contain appreciable amounts of naturally occurring vitamin D, with fatty fish being a notable exception (cod liver oil, in particular). For that reason, milk is commonly fortified with either D₂ or, more recently, D₃. Why milk? Because milk is rich in [calcium](#), which vitamin D helps your intestines absorb. For the same reason, yogurt, cheese, soy milk, and breakfast cereal are also commonly fortified with D₂ or D₃. Other commonly fortified foods include margarine, bread, and fruit juice (orange juice, in particular). As usual, which foods get fortified, if any, vary by country, based on local laws and policies.

How to take *vitamin D*

First, you should determine if you really need to supplement vitamin D by checking your current vitamin D levels — your [blood levels of 25-hydroxyvitamin D](#) (25(OH)D).



Reference: Institute of Medicine. [Overview of Vitamin D](#) (chapter 3 in *Dietary Reference Intakes for Calcium and Vitamin D*. The National Academies Press. 2011. DOI:[10.17226/13050](https://doi.org/10.17226/13050))

In case of *deficiency*, a medically supervised intervention will be needed. *Do not begin any intervention without discussing it with your physician*. Common medical interventions include taking 50,000 IU (1,250 mcg) of D₂ or D₃ at least three times a week for six to eight weeks, though people with a borderline

deficiency may not need as high a dose. At the end of this intervention, if vitamin D levels are above 30 nmol/L (12 ng/mL), a daily dose of 400–1,000 IU (20–25 mcg) is commonly used for maintenance.

In case of *inadequacy*, 800–2,000 IU (20–50 mcg) of D₃ per day is likely to raise vitamin D levels to an adequate level, at which point 400–1,000 IU (20–25 mcg) per day should suffice for maintenance.

In case of *adequate* vitamin D levels, a vitamin D supplement may not be necessary, especially if you spend a lot of time outside and live near the equator. However, taking 400–600 IU (10–15 mcg) of D₃ per day may help maintain vitamin D levels in the adequate range, particularly during the colder, darker months, when you are least likely to synthesize enough vitamin D from sun exposure.

In case of *high* vitamin D levels (which can cause adverse effects), seek the help of a medical professional. Of course, stop taking any supplement containing vitamin D, unless otherwise instructed by a medical professional.

If you do not know your vitamin D levels and cannot get them tested but are still intent on taking a vitamin D supplement, it would be prudent to limit yourself to a maintenance dose of 400 IU (10 mcg) of D₃ per day. Alternatively, you could track your food intake for a week to determine your average vitamin D intake, then select a complementary dose to reach your RDA.

Recommended Dietary Allowance (RDAs) for vitamin D (IU*)

AGE	MALE	FEMALE	PREGNANT	LACTATING
0–12 months	400*	400*	—	—
1–13 years	600	600	—	—
14–18 years	600	600	600	600
19–50 years	600	600	600	600
51–70 years	600	600	—	—
>70 years	800	800	—	—

* 40 IU = 1 mcg | ** Adequate intake (AI)

Reference: Institute of Medicine. [Dietary Reference Intakes for Adequacy: Calcium and Vitamin D](#) (chapter 5 in *Dietary Reference Intakes for Calcium and Vitamin D*. The National Academies Press. 2011. DOI:[10.17226/13050](#))

If the maintenance doses in the paragraphs above prove insufficient, as could be the case notably if your BMI is over 30^[82] or if you suffer from poor vitamin D absorption or processing (due to a problem with your kidneys, liver, or gastrointestinal tract), you could switch to 1,000–2,000 IU (25–50 mcg) of D₃ per day.

Vitamin D being fat-soluble, it is better absorbed when taken with a fat-containing food or supplement (e.g., [fish oil](#)).

Promising Supplements

Beta-Alanine

What makes *beta-alanine* a promising option

When ingested, the nonessential amino acid beta-alanine (aka β -alanine) binds with the essential amino acid histidine to create carnosine. Carnosine has antioxidant properties; it also buffers lactic acid during exercise, which delays muscle fatigue.

The body cannot synthesize enough carnosine without enough beta-alanine, and it cannot synthesize enough beta-alanine to compensate for a dietary deficiency. Since beta-alanine and carnosine can only be found in meat products, vegetarians and [vegans](#) have lower than optimal carnosine levels (as do elderly people) and may benefit from beta-alanine supplementation.

How to take *beta-alanine*

Take 4–6 g/day.^[83] While beta-alanine can be taken at any time of the day, it may be better absorbed with food.

A common side-effect of beta-alanine is [paresthesia](#) (a tingling sensation, as when your leg “falls asleep”). Taking smaller doses throughout the day or using time-release formulations can help reduce the prickling sensation on the face and skin. Paresthesia is harmless, if potentially unpleasant.

Unproven Supplements

Omega 3-6-9

What makes *omega 3-6-9* an unproven option

Your body can make omega-9 fatty acids when it needs them, and you probably get more than enough omega-6 fatty acids through your diet. The only kind of polyunsaturated fatty acids you might lack are [omega-3](#) fatty acids, so you should not purchase “omega 3-6-9” supplements.

Inadvisable Supplements

Of the supplements we have reviewed, none currently fit the above description.

FAQ

Q. What about the supplements not covered in this guide?

Our guides are regularly updated, often with new supplements. We prioritize assessing (and reassessing) the most popular of them and those most likely to work. However, if there is a specific supplement you'd like to see covered in a future update, please let us know by [filling out this survey](#).

Q. Can I add a supplement not covered in this guide to my combo?

Supplement with your current combo for a few weeks before attempting any change. Talk to your physician and [research each potential addition](#). Check for known negative interactions with other supplements and pharmaceuticals in your current combo, but also for synergies. If two supplements are synergistic or additive in their effects, you might want to use lower doses of each.

Q. Can I modify the recommended doses?

If a supplement has a recommended dose range, stay within that range. If a supplement has a precise recommended dose, stay within 10% of that dose. Taking more than recommended could be counterproductive or even dangerous. Taking less could render the supplement ineffective, yet starting with half the regular dose could be prudent — especially if you know you tend to react strongly to supplements or pharmaceuticals.

Q. At what time should I take my supplements?

The answer is provided in the “How to take” section of a supplement entry whenever the evidence permits. Too often, however, the evidence is either mixed or absent. Starting with half the regular dose can help minimize the harm a supplement may cause when taken during the day (e.g., [fatigue](#)) or in the evening (e.g., [insomnia](#)).

Q. Should I take my supplements with or without food?

The answer is provided in the “How to take” section of a supplement entry whenever the evidence permits. Too often, however, the evidence is either mixed or absent. Besides, a supplement's digestion, absorption, and metabolism can be affected differently by different foods. Fat-soluble vitamins ([A](#), [D](#), [E](#), [K](#)), for instance, are better absorbed with a small meal containing fat than with a large meal containing little to no fat.

Q. What are DRI, RDA, AI, and UL?

The [Dietary Reference Intakes](#) (DRIs) is a system of nutrition recommendations designed by the Institute of Medicine (a US institution now known as the [Health and Medicine Division](#)). RDA, AI, and UL are part of this system.

- Contrary to what the name suggests, a *Recommended Dietary Allowance* (RDA) doesn't represent an *ideal* amount; it represents the *minimum* you need in order to avoid deficiency-related health issues. More precisely, it represents an amount just large enough to meet the minimum requirements of 97.5% of healthy males and females over all ages — which implies that the RDA is too low for 2.5% of healthy people.
- The *Adequate Intake* (AI) is like the RDA, except that the number is more uncertain.
- The *Tolerable Upper Intake Level* (UL) is the maximum safe amount. More precisely, it is the maximum daily amount deemed to be safe for 97.5% of healthy males and females over all ages — which implies that the UL is too high for 2.5% of healthy people.

As a general rule, a healthy diet should include at least the RDA of each nutrient — but less than this nutrient's UL. This rule has many exceptions, though. For instance, people who sweat more need more salt (i.e., sodium), whereas people who take [metformin](#) (a diabetes medicine) need more [vitamin B12](#).

Moreover, the DRIs are based on the median weight of [adults](#) and [children](#) in the United States. Everything else being equal (notably age, sex, and percentage of body fat), you likely need a lesser amount of nutrients if you weigh less, and vice versa if you weigh more. The numbers, however, are not proportional — if only because the brains of two people of very different weights have very similar needs. So you can't just double your RDIs for each nutrient if you weigh twice as much as the median adult of your age and sex (even if we overlook that people weighing the same can differ in many respects, notably body fat).

Q. What's the difference between elemental iodine/iron and other kinds of iodine/iron?

"Elemental" refers to the weight of the mineral by itself, separately from the compound bound to it. For instance, consuming 13 mg of potassium iodide means consuming 10 mg of elemental iodine, whereas consuming 100 mg of ferrous fumarate means consuming 33 mg of elemental iron.

Product labels display the elemental dosage. On a label, "100 mcg of iodine (as potassium iodide)" means 100 mcg of elemental iodine (and 30 mcg of potassium), whereas "8 mg of iron (as ferrous fumarate)" means 8 mg of elemental iron (and 16 mg of fumaric acid).

Q. Isn't soy protein bad for males?

Phytoestrogens are plant compounds structurally similar to estradiol, the main [estrogen](#) in males and premenopausal females. Because soy contains [isoflavones](#), a type of phytoestrogen, concern has been raised about soy affecting male health.





To this day, two case reports have documented adverse effects ([gynecomastia](#), [hypogonadism](#), reduced [libido](#), and [erectile dysfunction](#)) from an estimated 360 mg of soy isoflavones per day for 6–12 months. However, a meta-analysis of 15 *randomized controlled trials* (RCTs, a much higher level of evidence than

case reports) found that males' levels of [total and free testosterone](#) were not notably affected by either 60–240 mg of isoflavones or 10–70 grams of soy protein per day.

Accordingly, a couple of scoops of soy protein powder are unlikely to have estrogenic effects in males. If you'd like to take more, however, look for a soy protein concentrate or isolate produced through the [alcohol-wash method](#), which dramatically lowers the isoflavone content.^[84]

Keep in mind that the isoflavone content of different soy products can vary depending on several factors, such as the variety of soybeans used, differences in growing and storage conditions, and differential food processing techniques employed.^[85] You can see how it varies below.

Isoflavone content of common soy foods

Food category	Food	Milligrams of isoflavones per 100 g of food		
		Average	Minimum	Maximum
 Traditional unfermented soy foods	Edamame	18	14	19
	Soybeans (boiled)	65	23	128
	Soybeans (raw)	155	10	440
	Soybean sprouts	34	0	107
	Soy milk (unsweetened)	11	1	31
	Soy nuts	148	2	202
	Tofu	30	3	142
 Traditional fermented soy foods	Miso	41	3	100
	Miso soup	1.5	1.5	1.5
	Miso soup mix (powder)	70	54	126
	Natto	82	46	124
	Soy sauce	1	0	3
	Tempeh	61	7	179
 Second-generation soy foods	Soy-based veggie “meats”	9	0	23
	Soy cheeses	26	3	59
	Soy yogurt	33	10	70
 Soy flours and protein powders	Soy flour (defatted)	151	74	324
	Soy flour (full-fat)	165	130	260
	Soy infant formula (powder)	28	21	31
	Soy protein concentrate (alcohol wash)	12	2	32
	Soy protein concentrate (water wash)	95	61	167
	Soy protein isolate	91	46	200

Reference: USDA FoodData Central Databases. Accessed Jan 18, 2019. <https://fdc.nal.usda.gov/>

Q. Don't dietary proteins _reduce_ bone density?

More [protein](#) in the diet has been linked to more [calcium](#) in the urine. Two reasons have been suggested to explain this phenomenon:

- Your body draws from its calcium stores (in bones) to buffer the acid load caused by dietary protein. This has led researchers to suggest that higher protein intake could increase bone loss.^[86]
- Most studies that looked at protein intake and calcium excretion list dairy products as a protein source,^[87] so higher urinary calcium could simply be the result of higher calcium intake (i.e., more calcium in, more calcium out).

Therefore, looking only at calcium _excretion_ wasn't enough. Subsequent studies showed that dietary protein promotes dietary-calcium absorption^[88] and that high protein intake "promotes bone growth and retards bone loss whereas low-protein diet is associated with higher risk of hip fractures."^[89] High-protein diets have also been shown to modestly suppress the decrease in [bone mineral density](#) caused by weight loss.^[90]

What happens is that when you ingest more protein, you absorb more of the calcium in your food, so less calcium ends up in your feces. Later, your body gets rid of the calcium it doesn't need, so more calcium ends up in your urine, but not as much as would have otherwise ended in your feces.^[91] Therefore, an increase in protein intake leads to an overall decrease in calcium excretion, which points to an increase in calcium retention. High-protein diets also raise your *insulin-like growth factor-1* ([IGF-1](#)),^[92] which promotes notably bone growth.^[93]

All in all, current evidence suggests that *protein's effect on bones is either neutral or beneficial*.^{[91][94]}

Q. Since the body makes carnosine out of beta-alanine and histidine, should I also supplement histidine?

It isn't necessary. If you consume enough protein, your muscles already have all the histidine they need to produce more carnosine.

Q. Still, why beta-alanine? Wouldn't it be simpler to supplement carnosine directly?

Since carnosine simply gets digested into [beta-alanine](#) and histidine, and since your muscles already have enough histidine, carnosine supplementation has no advantage over beta-alanine supplementation — especially since beta-alanine is cheaper.

Q. Why is there no mention in this guide of greens supplements?

Barley, [chlorella](#), [spirulina](#) ... Many are the plant-based supplements aimed at vegetarians and [vegans](#). Some

may be useful — for instance, preliminary evidence suggests that spirulina can fight inflammatory diseases. However, none of those “greens” products benefit vegetarians or vegans more than omnivores, so none were included in this guide.

Q. I’ve heard that I should “load” creatine. What does that mean?

Loading creatine means taking a high daily dose for a few days before moving down to a smaller maintenance dose, which can be taken indefinitely. This is not necessary for effective supplementation, however; benefits may be felt sooner through loading, but they normalize after a few weeks.

If you wish to load creatine, take 20–25 g/day for 7 days (splitting your daily intake into smaller doses, taking them with some food, and drinking more fluids may help prevent intestinal discomfort). Take 5 g/day thereafter.

Q. Creatine doesn’t seem to work for me. What should I do?

Some people are creatine nonresponders: the creatine they ingest largely fails to reach their muscles. Alternate forms of creatine, such as creatine ethyl-ester, have been marketed to nonresponders, but they lack scientific support. Currently, the best way to lessen creatine nonresponse is to take 5 grams twice a day, each time with protein and carbs, preferably close to a time of muscle contraction (i.e., before or after your workout).

Note that even if supplemental creatine fails to enter your muscles it can still benefit you in other ways, such as by improving your body’s methylation status (methylation being a way for your cells to help manage gene expression).

Q. What can I do to help prevent my fish oils from oxidizing?

Since fish oil is primarily polyunsaturated fat, it is prone to becoming rancid and oxidizing. Oxidation largely depends on exposure to heat, light, and oxygen. The addition of antioxidants to the final product can reduce the rate of oxidation during storage. [Vitamin E](#) is typically used, but there’s a lot of research on other antioxidants like [carnosic acid](#) suggesting they might be superior.^[95]

Part of the responsibility for ensuring fish oil remains unoxidized is on the buyer. Exposure of fish oil to light, heat, and oxygen accelerates the oxidation of the oil, with the magnitude of damage depending on the length and degree of exposure. Once you buy the supplement, it is prudent to store it in a cool place away from light, such as the fridge.

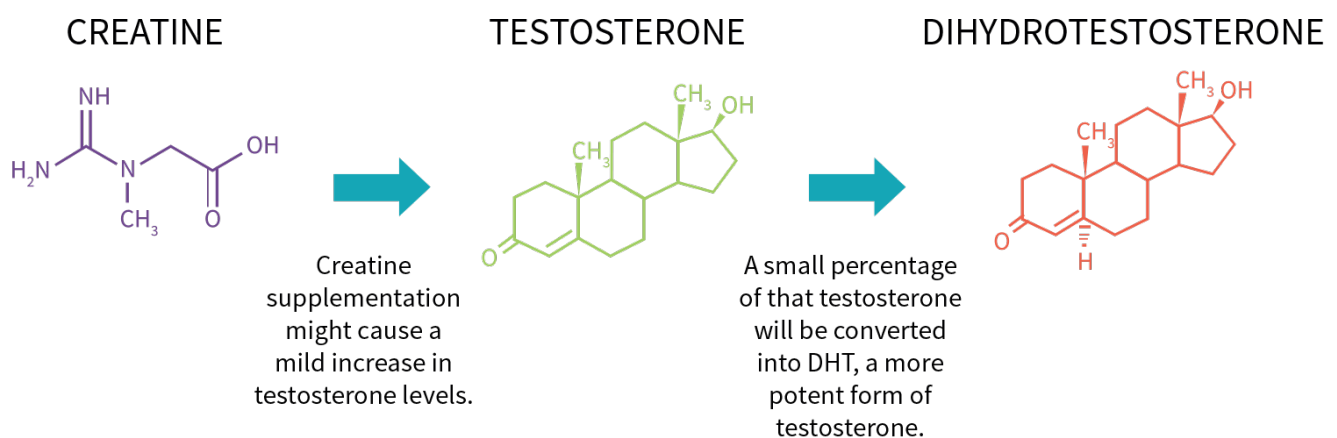
If you buy oil in a bottle, the bottle should be tinted to prevent light from getting through and small enough that you can work through it in a month or two. After all, oxygen gets in the bottle every time you open it. Some fish oil bottles come with a pump, which can help reduce oxygen exposure. Buying capsules instead of bottles can also help prevent oxidation.

Q. Will creatine cause hair loss?

The idea that creatine *might* increase hair loss stems from a single randomized controlled trial (RCT) whose participants (20 healthy, young, male rugby players) saw a small but statistically significant increase in *dihydrotestosterone* (DHT) after supplementing with creatine for 21 days.^[96] When DHT, a potent metabolite of *testosterone*, binds to DHT receptors on the hair follicles of the scalp, those follicles may shrink and stop producing hair.^{[97][98]}

To date, this RCT is the only one to have tested creatine's effects on DHT. However, a number of RCTs have examined creatine's effects on testosterone. Out of 12 additional RCTs, two saw a significant increase in testosterone,^{[99][100]} but 10 saw no effect.^{[96][101][102][103][104][105][106][107][108][109]} Of those 12 RCTs, five also tested creatine's effects on *free testosterone*, the form that gets converted into DHT, and all saw no significant increases.^{[102][101][104][106][108]}

A proposed mechanism behind creatine's effect on testosterone



Creatine *could* nonsignificantly increase free testosterone yet significantly increase DHT (i.e., a small increase in free testosterone, which can convert into DHT, could lead to a much greater increase in total DHT). So while it's *technically* possible that creatine might have some effect on hair loss, current evidence and mechanistic data indicate it's quite unlikely.

A summary of creatine-testosterone studies

BETWEEN-GROUP EFFECT	STUDY	SAMPLE SIZE	POPULATION	AVG AGE	DURATION	DOSE	EFFECT ON TESTOSTERONE
Significant	Arazi 2015	20	Active males	20	1 week	20 g/day	↑
	Vatani 2011	20	Trained males	20	6 days	20 g/day	↑
Mixed Results	van der Merwe 2009	20	Male rugby players	18	3 weeks	25 g/day loading 5 g/day maintenance	↑ DHT ↔ Test
No effect	Cook 2011		Male rugby players	20	10 weeks	4.5 g and 9 g	↔
	Cooke 2014	20	Active males	61	12 weeks	20 g/day loading Then 0.1 g/kg 3x/week (avg. 8.8 g/day)	↔

BETWEEN-GROUP EFFECT	STUDY	SAMPLE SIZE	POPULATION	AVG AGE	DURATION	DOSE	EFFECT ON TESTOSTERONE
	Crowe 2003	28	Male rugby players	25	6 weeks	3 g/day HMB* + 3 g/day creatine	↔
	Eijnde 2001	11	untrained males	20	8 days	20 g/day	↔
	Faraji 2010	20	Male Sprinters	21	1 week	20 g/day	↔
	Hoffman 2006	33	Male football players	College	10 weeks	10.5 g/day	↔
	Rhimji 2010	27	Trained males	21	1 week	20 g/day	↔
	Tyka 2015**	19	Male runners	19–30***	6 weeks	0.07 g/kg of lean body mass	↔
	Volek 1997	13	Active males	23	1 week	25 g/day	↔
	Volek 2004	17	Trained males	21	6 weeks	20 g/day loading 4 g/day maintenance	↔

* While there was no creatine-only group, studies have not shown HMB to independently affect testosterone. [\[110\]\[111\]\[112\]\[113\]](#)

** This study used creatine malate instead of creatine monohydrate.

*** This study reported an age range but not an average age.

References

1. Leitzmann C [Vegetarian nutrition: past, present, future](#). *Am J Clin Nutr.* (2014 Jul)
2. Pribis P, Pencak RC, Grajales T [Beliefs and attitudes toward vegetarian lifestyle across generations](#). *Nutrients.* (2010 May)
3. Pawlak R [Vegetarian Diets in the Prevention and Management of Diabetes and Its Complications](#). *Diabetes Spectr.* (2017 May)
4. Sammataro D, Weiss M [Comparison of productivity of colonies of honey bees, *Apis mellifera*, supplemented with sucrose or high fructose corn syrup](#). *J Insect Sci.* (2013)
5. Clarys P, Deliens T, Huybrechts I, Deriemaeker P, Vanaelst B, De Keyzer W, Hebbelinck M, Mullie P [Comparison of nutritional quality of the vegan, vegetarian, semi-vegetarian, pesco-vegetarian and omnivorous diet](#). *Nutrients.* (2014 Mar 24)
6. Ru-Yi Huang, Chuan-Chin Huang, Frank B Hu, Jorge E Chavarro [Vegetarian Diets and Weight Reduction: a Meta-Analysis of Randomized Controlled Trials](#). *J Gen Intern Med.* (2016 Jan)
7. Alwarith J, Kahleova H, Rembert E, Yonas W, Dort S, Calcagno M, Burgess N, Crosby L, Barnard ND [Nutrition Interventions in Rheumatoid Arthritis: The Potential Use of Plant-Based Diets. A Review](#). *Front Nutr.* (2019 Sep 10)
8. Orlich MJ, Singh PN, Sabaté J, Jaceldo-Siegl K, Fan J, Knutsen S, Beeson WL, Fraser GE [Vegetarian dietary patterns and mortality in Adventist Health Study 2](#). *JAMA Intern Med.* (2013 Jul 8)
9. Key TJ, Appleby PN, Spencer EA, Travis RC, Roddam AW, Allen NE [Mortality in British vegetarians: results from the European Prospective Investigation into Cancer and Nutrition \(EPIC-Oxford\)](#). *Am J Clin Nutr.* (2009 May)
10. Archer E, Lavie CJ, Hill JO [The Failure to Measure Dietary Intake Engendered a Fictional Discourse on Diet-Disease Relations](#). *Front Nutr.* (2018 Nov 13)
11. Archer E, Pavea G, Lavie CJ [The Inadmissibility of What We Eat in America and NHANES Dietary Data in Nutrition and Obesity Research and the Scientific Formulation of National Dietary Guidelines](#). *Mayo Clin Proc.* (2015 Jul)
12. Miller TM, Abdel-Maksoud MF, Crane LA, Marcus AC, Byers TE [Effects of social approval bias on self-reported fruit and vegetable consumption: a randomized controlled trial](#). *Nutr J.* (2008 Jun 27)
13. Dwyer JT, Krall EA, Coleman KA [The problem of memory in nutritional epidemiology research](#). *J Am Diet Assoc.* (1987 Nov)
14. Moore WJ, McGrievy ME, Turner-McGrievy GM [Dietary adherence and acceptability of five different diets, including vegan and vegetarian diets, for weight loss: The New DIETs study](#). *Eat Behav.* (2015 Dec)
15. Chan DS, Lau R, Aune D, Vieira R, Greenwood DC, Kampman E, Norat T [Red and processed meat and colorectal cancer incidence: meta-analysis of prospective studies](#). *PLoS One.* (2011)
16. Samraj AN, Pearce OM, Läubli H, Crittenden AN, Bergfeld AK, Banda K, Gregg CJ, Bingman AE, Secrest P, Diaz SL, Varki NM, Varki A [A red meat-derived glycan promotes inflammation and cancer progression](#). *Proc Natl Acad Sci U S A.* (2015 Jan 13)
17. Dinu M, Abbate R, Gensini GF, Casini A, Sofi F [Vegetarian, vegan diets and multiple health outcomes: A systematic review with meta-analysis of observational studies](#). *Crit Rev Food Sci Nutr.* (2017 Nov 22)
18. Aguilera JM [The food matrix: implications in processing, nutrition and health](#). *Crit Rev Food Sci Nutr.* (2019)
19. Hall KD, Ayuketah A, Brychta R, Cai H, Cassimatis T, Chen KY, Chung ST, Costa E, Courville A, Darcey V, Fletcher LA, Forde CG, Gharib AM, Guo J, Howard R, Joseph PV, McGehee S, Ouwerkerk R, Raisingier K, Rozga I, Stagliano M, Walter M, Walter PJ, Yang S, Zhou M [Ultra-Processed Diets Cause Excess Calorie Intake and Weight Gain: An Inpatient Randomized Controlled Trial of Ad Libitum Food Intake](#). *Cell Metab.* (2019 Jul 2)
20. Flood-Obbagy JE, Rolls BJ [The effect of fruit in different forms on energy intake and satiety at a meal](#). *Appetite.* (2009 Apr)
21. Blair A, Ritz B, Wesseling C, Freeman LB [Pesticides and human health](#). *Occup Environ Med.* (2015 Feb)
22. Jeong SH, Kang D, Lim MW, Kang CS, Sung HJ [Risk assessment of growth hormones and antimicrobial residues in meat](#). *Toxicol Res.* (2010 Dec)
23. Jaishankar M, Tseten T, Anbalagan N, Mathew BB, Beeregowda KN [Toxicity, mechanism and health effects of some heavy metals](#). *Interdiscip Toxicol.* (2014 Jun)
24. Buscail C, Sabate JM, Bouchoucha M, Torres MJ, Allès B, Hercberg S, Benamouzig R, Julia C [Association between self-reported vegetarian diet and the irritable bowel syndrome in the French NutriNet cohort](#). *PLoS One.* (2017 Aug 25)
25. Cummings JH, Macfarlane GT [Gastrointestinal effects of prebiotics](#). *Br J Nutr.* (2002 May)
26. Dionne J, Ford AC, Yuan Y, Chey WD, Lacy BE, Saito YA, Quigley EMM, Moayyedi P [A Systematic Review and Meta-Analysis Evaluating the Efficacy of a Gluten-Free Diet and a Low FODMAPs Diet in Treating Symptoms of Irritable Bowel Syndrome](#). *Am J Gastroenterol.* (2018 Sep)
27. Medawar E, Huhn S, Villringer A, Veronica Witte A [The effects of plant-based diets on the body and the brain: a systematic review](#). *Transl Psychiatry.* (2019 Sep 12)
28. Matta J, Czernichow S, Kesse-Guyot E, Hoertel N, Limosin F, Goldberg M, Zins M, Lemogne C [Depressive Symptoms and Vegetarian Diets: Results from the Constances Cohort](#). *Nutrients.* (2018 Nov 6)
29. Montgomery SA, Thal LJ, Amrein R [Meta-analysis of double blind randomized controlled clinical trials of acetyl-L-carnitine](#)

- [versus placebo in the treatment of mild cognitive impairment and mild Alzheimer's disease. *Int Clin Psychopharmacol.* \(2003 Mar\)](#)
30. Smeland OB, Meisingset TW, Borges K, Sonnewald U [Chronic acetyl-L-carnitine alters brain energy metabolism and increases noradrenaline and serotonin content in healthy mice. *Neurochem Int.* \(2012 Jul\)](#)
 31. Asadi M, Rahimlou M, Shishehbor F, Mansoori A [The effect of L-carnitine supplementation on lipid profile and glycaemic control in adults with cardiovascular risk factors: A systematic review and meta-analysis of randomized controlled clinical trials. *Clin Nutr.* \(2019 Feb 22\)](#)
 32. Serban MC, Sahebkar A, Mikhailidis DP, Toth PP, Jones SR, Muntner P, Blaha MJ, Andrica F, Martin SS, Borza C, Lip GY, Ray KK, Rysz J, Hazen SL, Banach M [Impact of L-carnitine on plasma lipoprotein\(a\) concentrations: A systematic review and meta-analysis of randomized controlled trials. *Sci Rep.* \(2016 Jan 12\)](#)
 33. Shang R, Sun Z, Li H [Effective dosing of L-carnitine in the secondary prevention of cardiovascular disease: a systematic review and meta-analysis. *BMC Cardiovasc Disord.* \(2014 Jul 21\)](#)
 34. Farshidfar F, Pinder MA, Myrie SB [Creatine Supplementation and Skeletal Muscle Metabolism for Building Muscle Mass- Review of the Potential Mechanisms of Action. *Curr Protein Pept Sci.* \(2017\)](#)
 35. Chami J, Candow DG [Effect of Creatine Supplementation Dosing Strategies on Aging Muscle Performance. *J Nutr Health Aging.* \(2019\)](#)
 36. Candow DG, Forbes SC, Chilibeck PD, Cornish SM, Antonio J, Kreider RB [Effectiveness of Creatine Supplementation on Aging Muscle and Bone: Focus on Falls Prevention and Inflammation. *J Clin Med.* \(2019 Apr 11\)](#)
 37. Gualano B, Rawson ES, Candow DG, Chilibeck PD [Creatine supplementation in the aging population: effects on skeletal muscle, bone and brain. *Amino Acids.* \(2016 Aug\)](#)
 38. Avgerinos KI, Spyrou N, Bougioukas KI, Kapogiannis D [Effects of creatine supplementation on cognitive function of healthy individuals: A systematic review of randomized controlled trials. *Exp Gerontol.* \(2018 Jul 15\)](#)
 39. Kreider RB, Kalman DS, Antonio J, Ziegenfuss TN, Wildman R, Collins R, Candow DG, Kleiner SM, Almada AL, Lopez HL [International Society of Sports Nutrition position stand: safety and efficacy of creatine supplementation in exercise, sport, and medicine. *J Int Soc Sports Nutr.* \(2017 Jun 13\)](#)
 40. [GOED Voluntary Monograph.](#)
 41. Albert BB, Derraik JG, Cameron-Smith D, Hofman PL, Tumanov S, Villas-Boas SG, Garg ML, Cutfield WS [Fish oil supplements in New Zealand are highly oxidised and do not meet label content of n-3 PUFA. *Sci Rep.* \(2015 Jan 21\)](#)
 42. Bannenberg G, Mallon C, Edwards H, Yeadon D, Yan K, Johnson H, Ismail A [Omega-3 Long-Chain Polyunsaturated Fatty Acid Content and Oxidation State of Fish Oil Supplements in New Zealand. *Sci Rep.* \(2017 May 3\)](#)
 43. Bengtson Nash SM, Schlabach M, Nichols PD [A nutritional-toxicological assessment of Antarctic krill oil versus fish oil dietary supplements. *Nutrients.* \(2014 Aug 28\)](#)
 44. Ottestad I, Retterstøl K, Myhrstad MC, Andersen LF, Vogt G, Nilsson A, Borge GI, Nordvi B, Brønner KW, Ulven SM, Holven KB [Intake of oxidised fish oil does not affect circulating levels of oxidised LDL or inflammatory markers in healthy subjects. *Nutr Metab Cardiovasc Dis.* \(2013 Jan\)](#)
 45. García-Hernández VM, Gallar M, Sánchez-Soriano J, Micol V, Roche E, García-García E [Effect of omega-3 dietary supplements with different oxidation levels in the lipidic profile of women: a randomized controlled trial. *Int J Food Sci Nutr.* \(2013 Dec\)](#)
 46. Clarke R, Refsum H, Birks J, Evans JG, Johnston C, Sherliker P, Ueland PM, Schneede J, McPartlin J, Nexø E, Scott JM [Screening for vitamin B-12 and folate deficiency in older persons. *Am J Clin Nutr.* \(2003 May\)](#)
 47. Stover PJ [Vitamin B12 and older adults. *Curr Opin Clin Nutr Metab Care.* \(2010 Jan\)](#)
 48. Rizzo G, Laganà AS, Rapisarda AM, La Ferrera GM, Buscema M, Rossetti P, Nigro A, Muscia V, Valenti G, Sapia F, Sarpietro G, Zigarelli M, Vitale SG [Vitamin B12 among Vegetarians: Status, Assessment and Supplementation. *Nutrients.* \(2016 Nov 29\)](#)
 49. Pawlak R, Lester SE, Babatunde T [The prevalence of cobalamin deficiency among vegetarians assessed by serum vitamin B12: a review of literature. *Eur J Clin Nutr.* \(2014 May\)](#)
 50. Juzeniene A, Nizauskaite Z [Photodegradation of cobalamins in aqueous solutions and in human blood. *J Photochem Photobiol B.* \(2013 May 5\)](#)
 51. Lonn E, Yusuf S, Arnold MJ, Sheridan P, Pogue J, Micks M, McQueen MJ, Probstfield J, Fodor G, Held C, Genest J Jr, Heart Outcomes Prevention Evaluation (HOPE) 2 Investigators [Homocysteine lowering with folic acid and B vitamins in vascular disease. *N Engl J Med.* \(2006 Apr 13\)](#)
 52. [chapter 9 in *Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B-6, Folate, Vitamin B-12, Pantothenic Acid, Biotin, and Choline.* The National Academies Press.. \(1998\)](#)
 53. Institute of Medicine [Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. The National Academies Press. \(2001\)](#)
 54. Busti F, Camprostrini N, Martinelli N, Girelli D [Iron deficiency in the elderly population, revisited in the hepcidin era. *Front Pharmacol.* \(2014 Apr 23\)](#)
 55. Smith DL [Anemia in the elderly. *Am Fam Physician.* \(2000 Oct 1\)](#)
 56. Kell DB [Towards a unifying, systems biology understanding of large-scale cellular death and destruction caused by poorly](#)

- [liganded iron: Parkinson's, Huntington's, Alzheimer's, prions, bactericides, chemical toxicology and others as examples. *Arch Toxicol.* \(2010 Nov\)](#)
57. Fang X, An P, Wang H, Wang X, Shen X, Li X, Min J, Liu S, Wang F [Dietary intake of heme iron and risk of cardiovascular disease: a dose-response meta-analysis of prospective cohort studies. *Nutr Metab Cardiovasc Dis.* \(2015 Jan\)](#)
 58. Qiao L, Feng Y [Intakes of heme iron and zinc and colorectal cancer incidence: a meta-analysis of prospective studies. *Cancer Causes Control.* \(2013 Jun\)](#)
 59. Institute of Medicine [Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids. *The National Academies Press.* \(2000\)](#)
 60. Joy JM, Vogel RM, Shane Broughton K, Kudla U, Kerr NY, Davison JM, Wildman REC, DiMarco NM [Daytime and nighttime casein supplements similarly increase muscle size and strength in response to resistance training earlier in the day: a preliminary investigation. *J Int Soc Sports Nutr.* \(2018 May 15\)](#)
 61. Institute of Medicine [Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids. *The National Academies Press.* \(2005\)](#)
 62. Rafii M, Chapman K, Owens J, Elango R, Campbell WW, Ball RO, Pencharz PB, Courtney-Martin G [Dietary protein requirement of female adults >65 years determined by the indicator amino acid oxidation technique is higher than current recommendations. *J Nutr.* \(2015 Jan\)](#)
 63. Rafii M, Chapman K, Elango R, Campbell WW, Ball RO, Pencharz PB, Courtney-Martin G [Dietary Protein Requirement of Men >65 Years Old Determined by the Indicator Amino Acid Oxidation Technique Is Higher than the Current Estimated Average Requirement. *J Nutr.* \(2016 Mar 9\)](#)
 64. Tang M, McCabe GP, Elango R, Pencharz PB, Ball RO, Campbell WW [Assessment of protein requirement in octogenarian women with use of the indicator amino acid oxidation technique. *Am J Clin Nutr.* \(2014 Apr\)](#)
 65. Elango R, Humayun MA, Ball RO, Pencharz PB [Evidence that protein requirements have been significantly underestimated. *Curr Opin Clin Nutr Metab Care.* \(2010 Jan\)](#)
 66. Schoenfeld BJ, Aragon AA [How much protein can the body use in a single meal for muscle-building? Implications for daily protein distribution. *J Int Soc Sports Nutr.* \(2018 Feb 27\)](#)
 67. Jäger R, Kerksick CM, Campbell BI, Cribb PJ, Wells SD, Skwiat TM, Purpura M, Ziegenfuss TN, Ferrando AA, Arent SM, Smith-Ryan AE, Stout JR, Arciero PJ, Ormsbee MJ, Taylor LW, Wilborn CD, Kalman DS, Kreider RB, Willoughby DS, Hoffman JR, Krzykowski JL, Antonio J [International Society of Sports Nutrition Position Stand: protein and exercise. *J Int Soc Sports Nutr.* \(2017 Jun 20\)](#)
 68. Thomas DT, Erdman KA, Burke LM [American College of Sports Medicine Joint Position Statement. Nutrition and Athletic Performance. *Med Sci Sports Exerc.* \(2016 Mar\)](#)
 69. Devries MC, Sithamparapillai A, Brimble KS, Banfield L, Morton RW, Phillips SM [Changes in Kidney Function Do Not Differ between Healthy Adults Consuming Higher- Compared with Lower- or Normal-Protein Diets: A Systematic Review and Meta-Analysis. *J Nutr.* \(2018 Nov 1\)](#)
 70. Moore DR, Churchward-Venne TA, Witard O, Breen L, Burd NA, Tipton KD, Phillips SM [Protein ingestion to stimulate myofibrillar protein synthesis requires greater relative protein intakes in healthy older versus younger men. *J Gerontol A Biol Sci Med Sci.* \(2015 Jan\)](#)
 71. Morton RW, McGlory C, Phillips SM [Nutritional interventions to augment resistance training-induced skeletal muscle hypertrophy. *Front Physiol.* \(2015 Sep 3\)](#)
 72. Aragon AA, Schoenfeld BJ [Nutrient timing revisited: is there a post-exercise anabolic window?. *J Int Soc Sports Nutr.* \(2013 Jan 29\)](#)
 73. Xiang F, Lucas R, de Grujil F, Norval M [A systematic review of the influence of skin pigmentation on changes in the concentrations of vitamin D and 25-hydroxyvitamin D in plasma/serum following experimental UV irradiation. *Photochem Photobiol Sci.* \(2015 Dec\)](#)
 74. Meehan M, Penckofer S [The Role of Vitamin D in the Aging Adult. *J Aging Gerontol.* \(2014 Dec\)](#)
 75. Wacker M, Holick MF [Sunlight and Vitamin D: A global perspective for health. *Dermatoendocrinol.* \(2013 Jan 1\)](#)
 76. Ko JA, Lee BH, Lee JS, Park HJ [Effect of UV-B exposure on the concentration of vitamin D₂ in sliced shiitake mushroom \(*Lentinus edodes*\) and white button mushroom \(*Agaricus bisporus*\). *J Agric Food Chem.* \(2008 May 28\)](#)
 77. Jasinghe VJ, Perera CO, Barlow PJ [Bioavailability of vitamin D₂ from irradiated mushrooms: an in vivo study. *Br J Nutr.* \(2005 Jun\)](#)
 78. Lehmann B, Genehr T, Knuschke P, Pietzsch J, Meurer M [UVB-induced conversion of 7-dehydrocholesterol to 1 \$\alpha\$,25-dihydroxyvitamin D₃ in an in vitro human skin equivalent model. *J Invest Dermatol.* \(2001 Nov\)](#)
 79. Holick MF, MacLaughlin JA, Clark MB, Holick SA, Potts JT Jr, Anderson RR, Blank IH, Parrish JA, Elias P [Photosynthesis of previtamin D₃ in human skin and the physiologic consequences. *Science.* \(1980 Oct 10\)](#)
 80. Bikle DD [Vitamin D metabolism and function in the skin. *Mol Cell Endocrinol.* \(2011 Dec 5\)](#)
 81. [Lanolin. *Drugs and Lactation Database \(LactMed®\).* \(2006-05\)](#)
 82. Zittermann A, Ernst JB, Gummert JF, Börgermann J [Vitamin D supplementation, body weight and human serum 25-hydroxyvitamin D response: a systematic review. *Eur J Nutr.* \(2014\)](#)

83. Trexler ET, Smith-Ryan AE, Stout JR, Hoffman JR, Wilborn CD, Sale C, Kreider RB, Jäger R, Earnest CP, Bannock L, Campbell B, Kalman D, Ziegenfuss TN, Antonio J [International society of sports nutrition position stand: Beta-Alanine](#). *J Int Soc Sports Nutr.* (2015 Jul 15)
84. Anderson RL, Wolf WJ [Compositional changes in trypsin inhibitors, phytic acid, saponins and isoflavones related to soybean processing](#). *J Nutr.* (1995 Mar)
85. Erdman JW Jr, Badger TM, Lampe JW, Setchell KD, Messina M [Not all soy products are created equal: caution needed in interpretation of research results](#). *J Nutr.* (2004 May)
86. Barzel US, Massey LK [Excess dietary protein can adversely affect bone](#). *J Nutr.* (1998 Jun)
87. Schwingshackl L, Hoffmann G [Comparison of high vs. normal/low protein diets on renal function in subjects without chronic kidney disease: a systematic review and meta-analysis](#). *PLoS One.* (2014 May 22)
88. Hunt JR, Johnson LK, Fariba Roughead ZK [Dietary protein and calcium interact to influence calcium retention: a controlled feeding study](#). *Am J Clin Nutr.* (2009 May)
89. Shams-White MM, Chung M, Du M, Fu Z, Insogna KL, Karlson MC, LeBoff MS, Shapses SA, Sackey J, Wallace TC, Weaver CM [Dietary protein and bone health: a systematic review and meta-analysis from the National Osteoporosis Foundation](#). *Am J Clin Nutr.* (2017 Jun)
90. Wright CS, Li J, Campbell WW [Effects of Dietary Protein Quantity on Bone Quantity following Weight Loss: A Systematic Review and Meta-analysis](#). *Adv Nutr.* (2019 Nov 1)
91. Calvez J, Poupin N, Chesneau C, Lassale C, Tomé D [Protein intake, calcium balance and health consequences](#). *Eur J Clin Nutr.* (2012 Mar)
92. Livingstone C [Insulin-like growth factor-I \(IGF-I\) and clinical nutrition](#). *Clin Sci (Lond).* (2013 Sep)
93. Yakar S, Rosen CJ, Beamer WG, Ackert-Bicknell CL, Wu Y, Liu JL, Ooi GT, Setser J, Frystyk J, Boisclair YR, LeRoith D [Circulating levels of IGF-1 directly regulate bone growth and density](#). *J Clin Invest.* (2002 Sep)
94. Fenton TR, Lyon AW, Eliasziw M, Tough SC, Hanley DA [Meta-analysis of the effect of the acid-ash hypothesis of osteoporosis on calcium balance](#). *J Bone Miner Res.* (2009 Nov)
95. Wang H, Liu F, Yang L, Zu Y, Wang H, Qu S, Zhang Y [Oxidative stability of fish oil supplemented with carnolic acid compared with synthetic antioxidants during long-term storage](#). *Food Chem.* (2011 Sep 1)
96. van der Merwe J, Brooks NE, Myburgh KH [Three weeks of creatine monohydrate supplementation affects dihydrotestosterone to testosterone ratio in college-aged rugby players](#). *Clin J Sport Med.* (2009 Sep)
97. Hamada K, Randall VA [Inhibitory autocrine factors produced by the mesenchyme-derived hair follicle dermal papilla may be a key to male pattern baldness](#). *Br J Dermatol.* (2006 Apr)
98. Trüb RM [Molecular mechanisms of androgenetic alopecia](#). *Exp Gerontol.* (2002 Aug-Sep)
99. Vatani DS, Faraji J, Soori R, Mogharnasi M [The effects of creatine supplementation on performance and hormonal response in amateur swimmers](#). *SCI SPORT.* (2011 NOV)
100. Arazi J, Rajmaninia F, Hosseini K, Asadi A [Effects of short term creatine supplementation and resistance exercises on resting hormonal and cardiovascular responses](#). *SCI SPORT.* (2015 APR)
101. Cooke MB, Brabham B, Buford TW, Shelmadine BD, McPheeters M, Hudson GM, Stathis C, Greenwood M, Kreider R, Willoughby DS [Creatine supplementation post-exercise does not enhance training-induced adaptations in middle to older aged males](#). *Eur J Appl Physiol.* (2014 Jun)
102. Cook CJ, Crewther BT, Kilduff LP, Drawer S, Gaviglio CM [Skill execution and sleep deprivation: effects of acute caffeine or creatine supplementation - a randomized placebo-controlled trial](#). *J Int Soc Sports Nutr.* (2011 Feb 16)
103. Crowe MJ, O'Connor DM, Lukins JE [The effects of beta-hydroxy-beta-methylbutyrate \(HMB\) and HMB/creatine supplementation on indices of health in highly trained athletes](#). *Int J Sport Nutr Exerc Metab.* (2003 Jun)
104. Hoffman J, Ratamess N, Kang J, Mangine G, Faigenbaum A, Stout J [Effect of creatine and beta-alanine supplementation on performance and endocrine responses in strength/power athletes](#). *Int J Sport Nutr Exerc Metab.* (2006 Aug)
105. Eijnde BO, Hespel P [Short-term creatine supplementation does not alter the hormonal response to resistance training](#). *Med Sci Sports Exerc.* (2001 Mar)
106. Volek JS, Ratamess NA, Rubin MR, Gómez AL, French DN, McGuigan MM, Scheett TP, Sharman MJ, Häkkinen K, Kraemer WJ [The effects of creatine supplementation on muscular performance and body composition responses to short-term resistance training overreaching](#). *Eur J Appl Physiol.* (2004 May)
107. Faraji J, Arazi J, Vatani D, Hakimi M [The effects of creatine supplementation on sprint running performance and selected hormonal responses](#). *S AFR J RES SPORT PH.* (2010)
108. Rahimi R, Faraji H, Vatani DS, Qaderi M [Creatine supplementation alters the body's hormonal response to exercise](#). *Kinesiology.* (2010 JAN)
109. Volek JS, Boetes M, Bush JA, Putukian M, Sebastianelli WJ, Jraemer WJ [Response of Testosterone and Cortisol Concentrations to High-Intensity Resistance Exercise Following Creatine Supplementation](#). *J STRENGTH COND RES.* (1997)
110. Wilson JM, Lowery RP, Joy JM, Walters JA, Baier SM, Fuller JC, Stout JR, Norton LE, Sikorski EM, Wilson SM, Duncan NM, Zanchi NE, Rathmacher J [β-Hydroxy-β-methylbutyrate free acid reduces markers of exercise-induced muscle damage and](#)

[improves recovery in resistance-trained men.](#) *Br J Nutr.* (2013 Jan 3)

111. Hoffman JR, Cooper J, Wendell M, Im J, Kang J [Effects of beta-hydroxy beta-methylbutyrate on power performance and indices of muscle damage and stress during high-intensity training.](#) *J Strength Cond Res.* (2004 Nov)
112. Portal S, Zadik Z, Rabinowitz J, Pilz-Burstein R, Adler-Portal D, Meckel Y, Cooper DM, Eliakim A, Nemet D [The effect of HMB supplementation on body composition, fitness, hormonal and inflammatory mediators in elite adolescent volleyball players: a prospective randomized, double-blind, placebo-controlled study.](#) *Eur J Appl Physiol.* (2011 Sep)
113. Slater GJ, Logan PA, Boston T, Gore CJ, Stenhouse A, Hahn AG [Beta-hydroxy beta-methylbutyrate \(HMB\) supplementation does not influence the urinary testosterone: epitestosterone ratio in healthy males.](#) *J Sci Med Sport.* (2000 Mar)