Examine®

Vegetarians & Vegans Supplement Guide

Written By: Mike Murray, Adel Moussa, & Antonis Damianou
Edited By: Molly Gregas
Reviewed By: Wyatt Brown, & Molly Gregas

Table of Contents

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, I've thought a lot about vegetarianism in the ensuing decades, 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 simply because of the *yuck* factor. Paul McCartney famously said, "If slaughterhouses had glass walls, everyone would be a vegetarian."

However, my field of expertise is not ethics 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?

Unlike most other dietary patterns, vegetarianism doesn't require that you track calories or macronutrients or consult a complex list of *yes* and *no* foods. It has only one rule:

Do not eat animals.

And veganism 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, although it is an animal product (removed from beehives and replaced with sucrose or high-fructose corn syrup).[4] And although 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 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 — but providing enough of *all* nutrients may prove difficult without the help of some key supplements.

So are vegetarian/vegan diets healthier?

Although vegetarianism has a long history and veganism is quickly growing in popularity, randomized trials on either diet pattern are still scarce. 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 evidence that 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 mentioned, 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 who are able to stick to a vegetarian diet are more likely to exercise, avoid smoking, 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 — for example, cardiovascular mortality is harder to study now than in earlier decades because, thankfully, the ratio of *nonfatal* to *fatal* heart attacks is increasing.

There are a variety of other important health outcomes, of course, outside of 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, which is present only in animal products, has been found in human tumors.[16]

The evidence is still sparse and has mostly come from animal studies, but one meta-analysis of human studies has linked vegetarian diets to less death from heart disease and has linked both vegetarian and vegan diets to less death from cancer.[17] However, it is important to note that the same meta-analysis found that a *healthy* plant-based diet that was rich in fruits, veggies, and whole grains were linked to less heart disease than was an *unhealthy* plant-based diet that was 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 comes 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 who were told to eat as much as they'd like gained significantly more weight when they were provided with ultraprocessed options than with less-processed 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 apples. 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 although a lot of people have strong opinions 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 that compare those to other diets are few. One question in particular needs answering: if the health benefits of vegetarianism and veganism are real and actually 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?

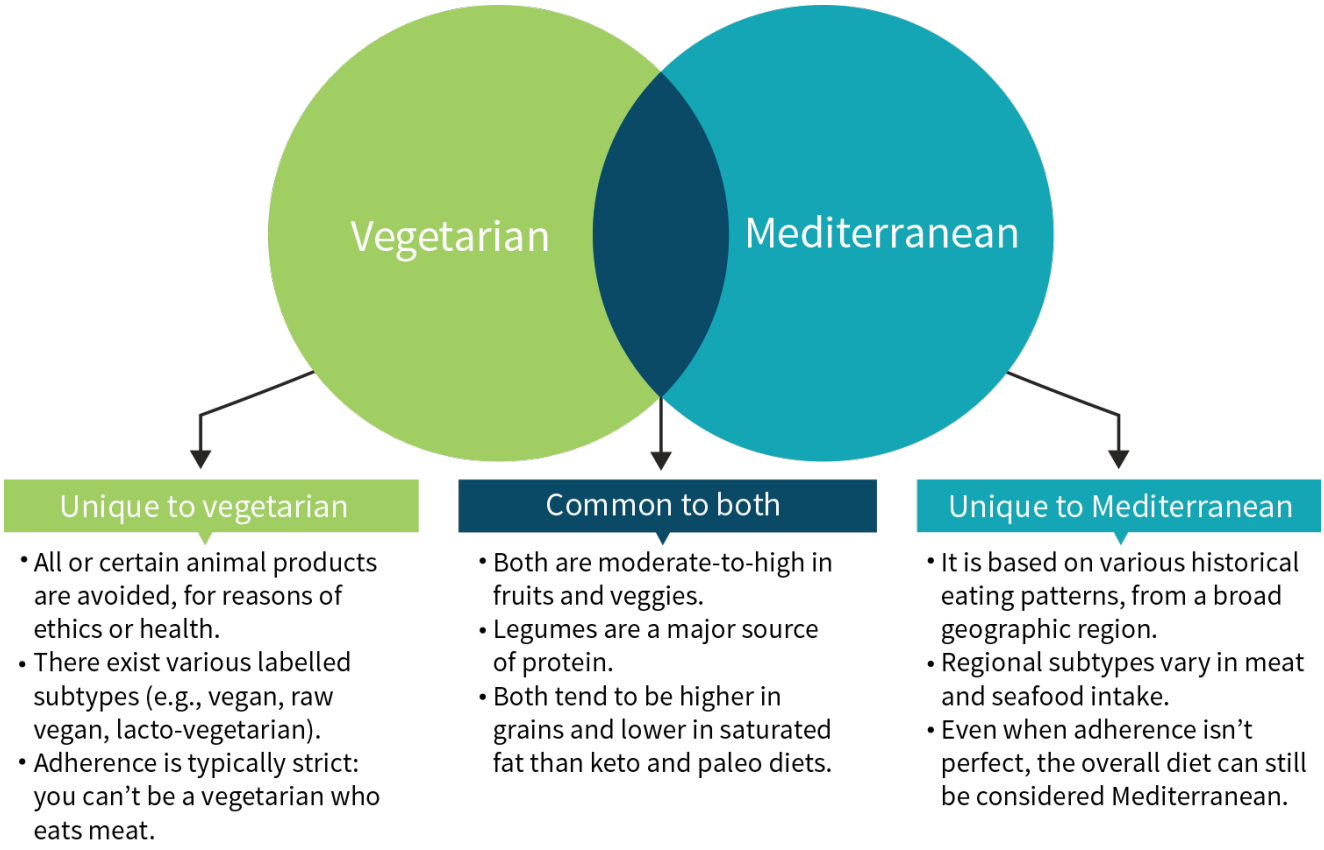
We don't have the answer. However, there is no denying that animal products contain nutrients that are difficult or even impossible to get from whole plant-based foods (nutrients such as EPA and DHA, found in fish). So it may be that a diet rich in whole plant-based foods with *some* animal products 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, although 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 (because 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

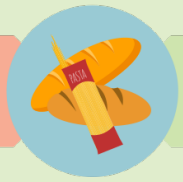
Vegan and vegetarian diets are linked to a higher incidence of certain digestive issues,[24] probably because of their usually high content of **fiber** and **FODMAPs**.

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 the production of a lot of gas, especially in people who quickly 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.

Tip: Food FODMAP content

High FODMAP Foods		Low FODMAP Foods
Asparagus, onions, garlic, legumes/pulses, sugar snap peas, beetroot, celery, sweet corn		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. [https://www.monashfodmap.com/](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, etc.). 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 humankind, 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 that 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 is rich 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 difficult 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

Disclaimer about supplement quality

We expect that readers will do their due diligence when choosing products. Depending on the manufacturer, supplements may have inaccurate labels (i.e., they contain too much or too little of the ingredients they claim or, in some cases, significant amounts of other ingredients not listed). They may also contain significant amounts of contaminants such as heavy metals or pesticides. It is also possible for supplements to contain ingredients that people are commonly allergic to, and it's important to be aware of the nonmedicinal ingredients as well. As a brief introduction to vetting manufacturers, we drew up a short list of steps you should take if a product has caught your interest.

> 💡 **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.

Core Combo

Vitamin B12 is the only supplement that we can be very sure is important, and it is only important for vegetarians and vegans who don't eat dairy and eggs regularly and who also don't consume enough through fortified foods.

Choline, iodine, and vitamin D are nutrients that may be worth supplementing for people who cannot be sure that they are getting enough. So are any of the others mentioned in this guide, for that matter, but the risk for deficiency is generally lower as long as one's diet is generally nutritious.

💡 **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 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 to 4 mg in one combo and 3 to 6 mg in the other, your new range becomes 2 to 6 mg. Always start with the lower end of the range — especially in this case, because 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

There is insufficient evidence to demonstrate a need for these supplements for vegetarians and vegans, but they are known to benefit omnivores too, and so the relative lack of these nutrients in the diets of vegetarians and vegans may make supplementation prudent.

For how to take beta-alanine, refer to the beta-alanine section of the Muscle Gain & Exercise Performance guide.

For how to take creatine, refer to the creatine section of the Muscle Gain & Exercise Performance guide.

For optimal protein intake, refer to both the vegetarians and vegans section and the athletes section of our Optimal Protein Intake Guide.

For vegetarians and vegans who are avoiding salt

Consume at least 150 µg of iodine daily with the core supplement.

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

For vegetarians who don't get enough sun

Review the vitamin D section.

What has changed since the last time?

It should be noted that we changed the names of our ranking categories. "Core" (the highest) is now "primary", "primary" is now "secondary", and "secondary" is now "promising". This nomenclature has already been implemented for some guides, but this is the first update to the Vegetarians & Vegans guide that uses this new terminology. For example, if it was a core supplement in the previous issue and now it's a secondary supplement in this issue, we'll say that it was a primary supplement in the previous issue and is now a secondary supplement.

Added:

- Choline
- Zinc

Changed ranking:

Carnitine

Downgraded from primary to unproven. Although it is generally lower in vegetarians and vegans, it is unclear whether this leads to significant consequences. It is unlikely that a lack of dietary carnitine will lead to deficiency levels.

Creatine

Downgraded from primary to promising. The evidence for cognitive benefits is weaker than when we wrote the original version, with a new study finding no effect on memory.

Omega-3

Downgraded from primary to promising. There is a lack of direct evidence that vegetarians and vegans need to take algae omega-3 supplements. It may still be prudent, however.

Iron

Downgraded from secondary to unproven. Although it's possible for some vegetarian diets to lead to low iron levels, as long as some attention is paid to obtaining sufficient iron from plant foods, it doesn't appear to be much of an issue in the general population.

Beta-alanine

Downgraded from promising to unproven. There's a lack of evidence that vegetarians and vegans uniquely benefit from taking beta-alanine beyond the benefits for all athletes regardless of diet. It might be true, but our new standards require more evidence from trials.

Removed:

Omega-3-6-9.

Although this is indeed an unnecessary supplement, very few people believed that it was important for

Vegetarians & Vegans to begin with.

Primary Supplements

Vitamin B12

What makes *vitamin B12* a primary option

Vitamin B12 is an essential water-soluble nutrient that is critical for brain health and cognitive function, the formation of healthy red blood cells, and synthesis of DNA.

Animal-based foods are naturally rich in vitamin B12. Vitamin B12 has also been detected in algae, but there is wide variation in bioavailability (the vitamin B12 that is found in some algae is inactive in humans) among species and products, and so it is currently not considered a reliable dietary source.[29][30] Vitamin B12 can also be obtained from fortified foods like breakfast cereals and nutritional yeast.

Consequently, dietary intakes of vitamin B12 are generally much higher in omnivores than in vegetarians and vegans.[31] Vegetarians and vegans are also at a higher risk of vitamin B12 deficiency.[31]

Because vegans don't consume foods that are naturally rich in vitamin B12, supplemental vitamin B12 is considered a primary option in this population, especially if the diet contains little-to-no foods that are fortified with vitamin B12.

Vegetarians are at a much lower risk of inadequate vitamin B12 status because their diets allow dairy products and eggs, but supplemental vitamin B12 may still be considered as a secondary option, particularly for older adults who have an impaired ability to absorb natural vitamin B12,[32] as well as in the context of a diet that contains limited amounts of animal-based foods.

Warnings about vitamin B12

According to some evidence, a high vitamin B12 level could increase the risk of certain cancers and decrease the risk of others. One study[33] found an association between elevated vitamin B12 levels and prostate cancer; however, it did not establish a causal relationship. A 2017 cohort study found an increased lung cancer risk for men who smoked and took relatively high doses of vitamin B12. Although this association doesn't necessarily mean that vitamin B12 caused the increased rate of lung cancer, it is certainly worth considering before supplementing in this population group.[34]

Conversely, another study found that a higher vitamin B12 intake was associated with a lower risk of colorectal cancer.[35]

In cardiovascular disease, the evidence also remains uncertain. A 2024 meta-analysis found that increased vitamin B12 levels were associated with an increase in cardiovascular disease mortality. However, this study looked at endogenous vitamin B12 (produced inside the body), not vitamin B12 intake, and this might indicate that vitamin B12 levels rise in the presence of cardiovascular disease.[36] Another study found that vitamin B12 had little impact on cardiovascular disease outcomes.[37] More studies are needed to assess supplemental vitamin B12 as a risk factor for cardiovascular disease.

How to take *vitamin B12*

The Recommended Dietary Allowance (RDA) for vitamin B12 for most adults is 2.4 micrograms (µg) per day. Supplements often contain much more than the RDA (500–2,000 µg per tablet), but this isn't a problem because the body excretes what it doesn't need. Additionally, the body is capable of storing vitamin B12 (about 2–3 milligrams),[38] which is slowly depleted over time. So, in the context of supplements containing relatively large amounts of vitamin B12 per tablet, daily supplementation is not required, and a couple of times per week is fine.

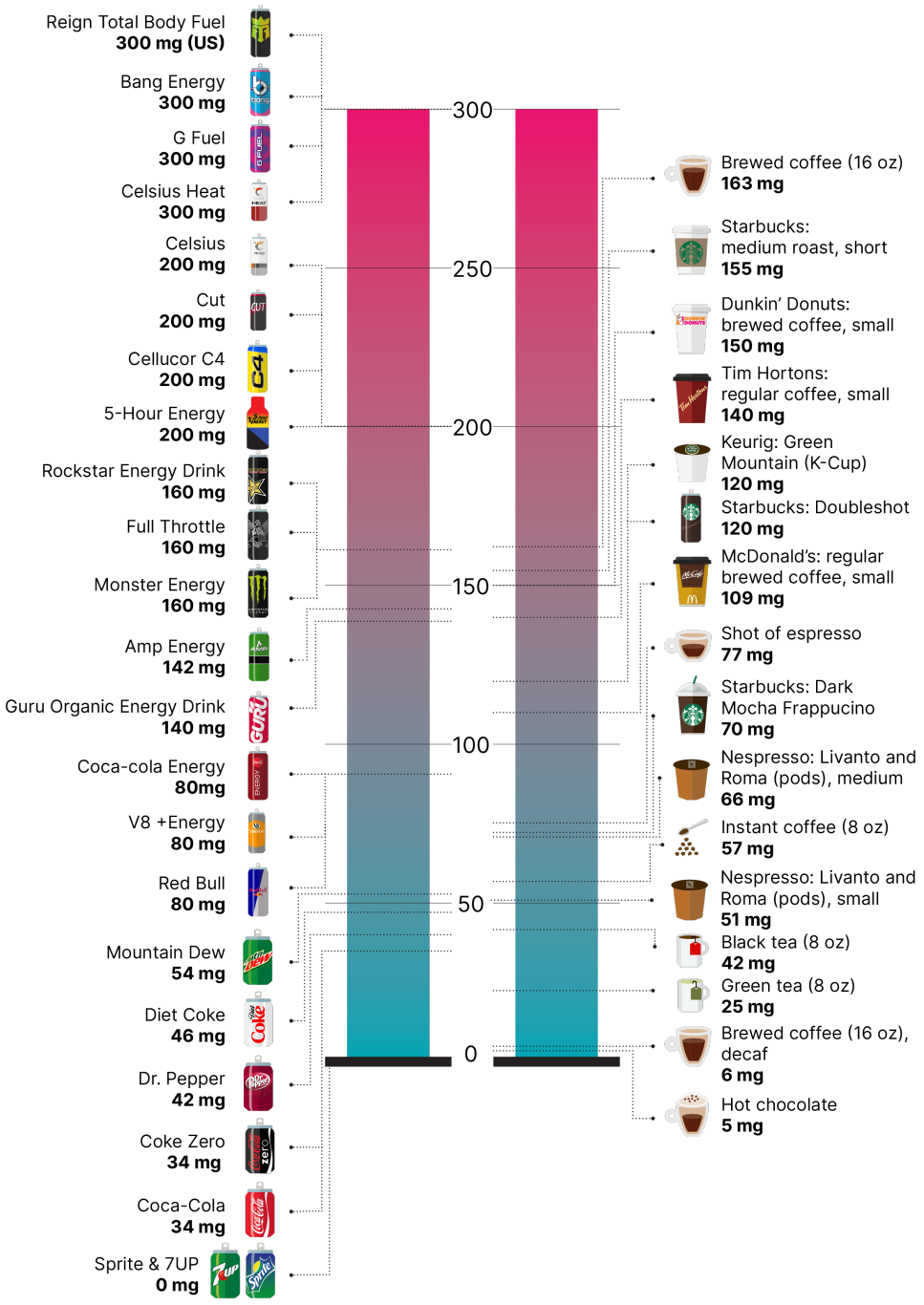
Recommended Dietary Allowance (RDA) for vitamin B_{12} (mcg)

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 B_{12} (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. DOI:10.17226/6015)

Some evidence suggests that supplementing with cyanocobalamin is more effective for improving vitamin B12 status than hydroxocobalamin.[39][40]



All 4 commonly supplemented B12 vitamers can degrade when exposed to UV rays,[41] but *cyano*cobalamin and *hydroxo*cobalamin are more stable (and widely available) than *methyl*cobalamin and *adenosyl*cobalamin.

Secondary Supplements

Choline

What makes *choline* a secondary supplement

Choline is essential for the structural integrity of cell membranes, as a precursor of acetylcholine, and as a methyl donor for methionine synthesis.[42][43] Choline deficiency has been linked to liver disease, cognitive dysfunction in offspring, and possible neurological disorders.[44] It is particularly important during early fetal development, and studies have shown that providing approximately twice the recommended amount of choline (930 mg vs. 480 mg) to pregnant women can positively affect the infant's information processing speed.[45] The primary sources of choline in the North American diet are eggs, which provide up to 430 milligrams of choline per 100 grams of egg, and meat, which provides less but still meaningful amounts.[42] However, despite high levels of choline in the staple foods of the classic omnivorous Western diet, more and more people appear to be failing to meet the RDA of 425 mg per day and 550 mg per day for adult nonlactating women and men, respectively — and this is a global phenomenon that's by no means limited to the U.S. or Europe.[46][47][44][48][49]

Currently, it is not entirely clear how much worse vegans and vegetarians fare in terms of choline intake. Recently, however, Graham et al. conducted an analysis of the nutritional adequacy of mass-market vegan recipes[50] and reported that a 2,000 kcal diet based on the vegan meals analyzed provided (on average) only 30% of the recommended daily intake of choline.

The potential lack of choline in vegan diets is demonstrated by scientific models that have calculated a choline deficit of 100 to 200 mg per day in individuals who were following either the USDA's own "Healthy Vegetarian Diet Pattern" or a standard vegan diet pattern.[51] According to the author, vegetarians and vegans should include alternative sources of choline in their diets, including (but not limited to) beans, peas, and lentils.

Table 1: Choline content of selected foods

Food	mg per serving	%DV
Beef liver, pan fried, 3 ounces	356	65
Egg, hard boiled, 1 large	147	27
Beef top round, separable lean only, braised, 3 ounces	117	21
Soybeans, roasted, ½ cup	107	19
Chicken breast, roasted, 3 ounces	72	13
Beef, ground, 93% lean meat, broiled, 3 ounces	72	13
Fish, cod, Atlantic, cooked, dry heat, 3 ounces	71	13
Potatoes, red, baked, flesh and skin, 1 large potato	57	10
Wheat germ, toasted, 1 ounce	51	9

Food	mg per serving	%DV
Beans, kidney, canned, ½ cup	45	8
Quinoa, cooked, 1 cup	43	8
Milk, 1% fat, 1 cup	43	8
Yogurt, vanilla, nonfat, 1 cup	38	7
Brussels sprouts, boiled, ½ cup	32	6
Broccoli, chopped, boiled, drained, ½ cup	31	6
Mushrooms, shiitake, cooked, ½ cup pieces	27	5
Cottage cheese, nonfat, 1 cup	26	5
Fish, tuna, white, canned in water, drained, 3 ounces	25	5
Peanuts, dry roasted, ¼ cup	24	4
Cauliflower, 1" pieces, boiled, drained, ½ cup	24	4
Peas, green, boiled, ½ cup	24	4
Sunflower seeds, oil roasted, ¼ cup	19	3
Rice, brown, long grain, cooked, 1 cup	19	3
Bread, pita, whole wheat, 1 large (6½ inch diameter)	17	3
Cabbage, boiled, ½ cup	15	3
Tangerine (mandarin orange), sections, ½ cup	10	2
Beans, snap, raw, ½ cup	8	1
Kiwi fruit, raw, ½ cup sliced	7	1
Carrots, raw, chopped, ½ cup	6	1
Apples, raw, with skin, quartered or chopped, ½ cup	2	0

Source: NIH

As the data in Table 1 and the sample menus in Table 2 show, vegetarian and vegan dieters can easily achieve adequate choline intakes of 450 to 550 mg per day by making the right dietary choices. On the other hand, an analysis of the choline content of mass-market vegan recipes[50] — as well as the suboptimal choline intakes predicted by USDA scientists for nonpregnant/nonlactating adults following the agency's own "Healthy Vegetarian Diet Pattern" —[51] suggest that the provision of additional choline in the form of dietary supplements or food fortification should be considered, if not continuously, then at least during pregnancy and lactation to ensure optimal maternal and infant health.

Table 2: Sample meal plan for omnivore, vegetarian, and vegan dieters showing that an adequate choline intake of 450 to 550 mg per day is achievable based on food alone. The choline values in parentheses are estimates. Exact values depend on individual portion sizes.

Meal Type	Omnivore	Vegetarian	Vegan
Breakfast	Scrambled eggs with spinach & cheese (180 mg), toast (13 mg), milk (41 mg)	Oatmeal (17 mg) with soy milk (57 mg), peanut butter (20 mg), berries (trace), toast (13 mg)	Smoothie with soy milk (57 mg), banana (12 mg), chia seeds (45 mg), spinach (8 mg), toast (13 mg)

Meal Type	Omnivore	Vegetarian	Vegan
Lunch	Grilled chicken breast (78 mg) with quinoa salad (22 mg) & yogurt (14 mg), bread	Vegetarian chili with lentils (31 mg), beans (80 mg), cottage cheese (13 mg), bread	Lentil soup with lentils (31 mg) & vegetables, bread, Brussels sprouts (35 mg)
Dinner	Baked salmon (250 mg) with roasted Brussels sprouts (35 mg) & brown rice (15 mg)	Tofu stir-fry (54 mg) with broccoli (63 mg) & quinoa (43 mg)	Tempeh stir-fry (120 mg) with cauliflower (28 mg) & quinoa (43 mg)

Overall, there's little doubt that omnivores, vegetarians, and vegans alike can meet their choline needs without supplements. However, many of the best sources of choline are controversial, and some people believe them to be unhealthy. For example, the German Society for Nutrition (DGE) recently recommended that people eat no more than one whole egg per week. And eggs are just the best-known example of a former staple food that today's dietary guidelines worldwide suggest that people avoid. And although this trend affects us all, its impact may be more pronounced for vegetarians and vegans, whose choice of dietary choline sources is already limited.

In view of its vital role in cell membrane structure and function, fat transport and metabolism, neurotransmitter synthesis, brain development and function, and DNA synthesis, supplementation may be warranted, and choline may be considered a secondary option for anyone who is falling short of their daily choline intake of 450 to 550 mg per day — vegetarians, vegans, and omnivores alike.

Warnings about choline

🔍 Digging Deeper: Will too much choline elevate TMAO and give me heart disease?

Although supplements in the form of choline bitartrate, citrate, or chloride can be used to compensate for otherwise inadequate intakes of this essential nutrient, their use has become controversial, primarily due to concerns about the choline metabolite *trimethylamine N-oxide* (TMAO). Produced by certain bacteria in our digestive tract, TMAO has been linked in several studies to atherosclerosis, heart disease, stroke, vascular dementia, and related conditions.[52][53][54]

The exact mechanism behind TMAO's adverse effects on vascular health is unclear; and scientists are puzzled because some foods that are particularly rich in TMAO and its precursors (such as fish) are associated with good vascular health.[55][56] This suggests a complex interaction among choline, gut microbes, and TMAO's potentially harmful effects on blood vessels that will require further research to untangle.

Upper intake limits for choline

Age	Dose
Children 1–8 years	1,000 mg/day
Children 9–13 years	2,000 mg/day
Adolescents 14–18 years	3,000 mg/day
Adults 19 years and older	3,500 mg/day

Reference: Institute of Medicine. Choline (chapter 12 in *Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate,*

Vitamin B12, Pantothenic Acid, Biotin, and Choline. The National Academies Press. 1998.)[57]

High/excessive intakes of choline can result in some side effects, including a fishy body odor, vomiting, excessive sweating and salivation, low blood pressure (hypotension), and liver toxicity.[58]

In addition, choline consumption has been shown to increase the production of *trimethylamine N-oxide* (TMAO), which is associated with an increased risk of cardiovascular disease. However, some studies indicate that the amount of choline consumed in 3 eggs per day does not elevate plasma TMAO levels.[59][60][61][62][63] Some studies have associated higher choline intakes with increased atrial fibrillation risk[64] and type 2 diabetes.[65]

How to take *choline*

For vegetarians and vegans who have fewer choline-rich options in their diets, supplements may be an easy and effective way to increase their intake to sufficient levels. Previously discussed research suggests that, for most people on vegetarian or vegan diets, the amount of supplemental choline that is required will range from 150 to 300 mg.

(mg)

AGE	MALE	FEMALE	PREGNANT	LACTATING
0–6 months	125	125	—	—
7–12 months	150	150	—	—
1–3 years	200	200	—	—
4–8 years	250	250	—	—
9–13 years	375	375	—	—
14–18 years	550	400	450	550
>18 years	550	425	450	550

Reference: Institute of Medicine. https://www.nap.edu/read/6015/chapter/14 (chapter 12 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. DOI:https://doi.org/10.17226/6015)

Given the potential formation of cardiovascular disease-promoting *trimethylamine N-oxide* (TMAO) in the gut, current research suggests that phospholipid-bound forms, as found naturally in most animal foods, are preferable.[66][67] Compared to the most readily available water-soluble supplemental form of choline, choline bitartrate, choline citrate, and choline chloride appear to be somewhat less likely to promote TMAO formation in the gut.[68] These forms would thus be a less expensive alternative to the otherwise recommended phosphatidylcholine supplements.

💡 **Always consider the actual choline content of a product**

When shopping for choline supplements, it's important to consider the actual choline content of the product. *Phosphatidylcholine* (PC), for example, contains only 13% to 20% choline, with the rest of the weight made up of its glycerol backbone, two fatty acids, and a phosphate group. So to get 150 to 300 mg of actual choline, look for a supplement with at least 750 to 1,200 mg of PC.

For citrate (38% choline), bitartrate (40%), chloride (75%), and CDP-choline (18%), the values are 400 to 800 mg, 375 to 750 mg, 200 to 400 mg, and 830 to 1,660 mg, respectively.[69][70]

If it is not possible to determine a person's individual choline deficit based on dietary records and the previously listed Adequate Intake (AI) suggestions from the National Institute of Health (NIH), taking 250 mg of choline would be a good place to start. This 250 mg of extra choline can be provided by 1,250 to 1,923 mg of lipid-bound phosphatidylcholine, 625 mg of choline bitartrate, 658 mg of choline citrate, or 333 mg of choline chloride.

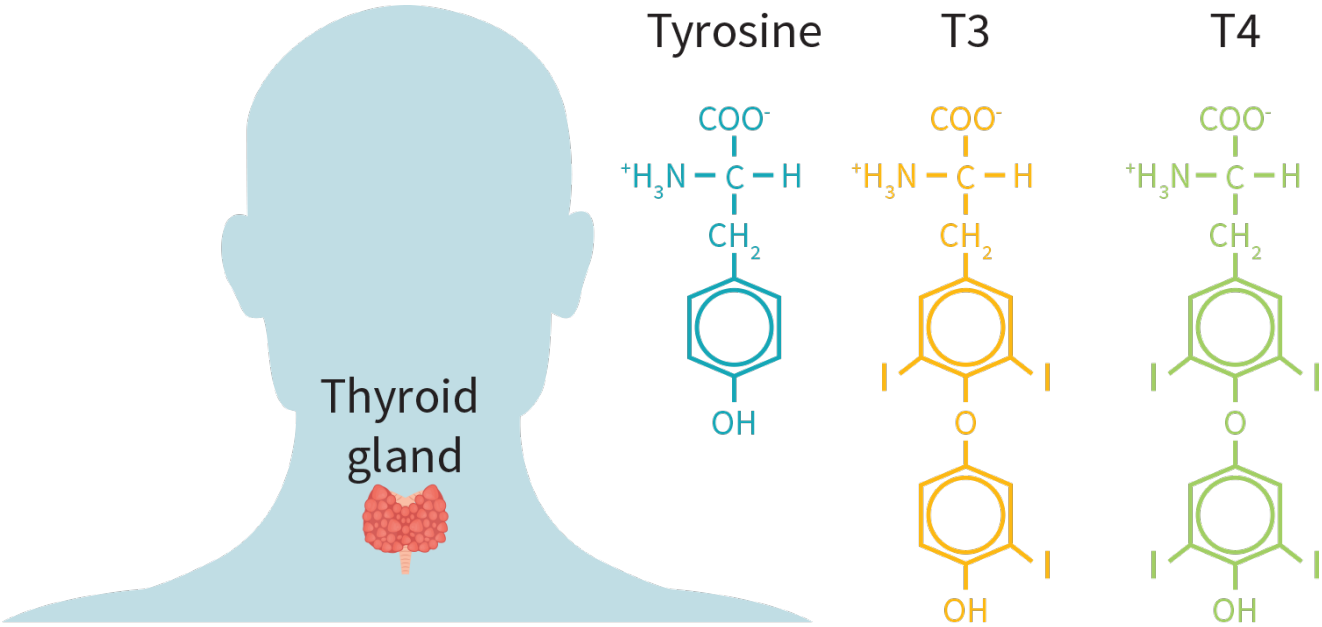
Be careful not to exceed the NIH recommendations: 3,500 mg per day for adults and correspondingly lower levels for children (see the "Upper intake limits for choline" table above for more information).

Iodine

What makes *iodine* a secondary option

Iodine is an essential mineral that is most notable for its role in thyroid function: it is a component of the hormones triiodothyronine (T_3) and thyroxine (T_4), which are involved in the regulation of various enzymes and metabolic processes.[71] Consequently, iodine deficiency leads to hypothyroidism (lower-than-normal thyroid function). Moreover, iodine deficiency has dire effects on the brain. Iodine deficiency in the mother prior to conception results in the development of cretinism in the offspring. In children and adults, iodine deficiency can lead to impaired mental function.[72]

The thyroid gland and thyroid hormones



Dairy products and seafood are the richest food sources of iodine. However, salt is iodized in most countries, and so a large proportion of daily iodine intake often comes from household salt (i.e., salt used while cooking and at the table) and the salt in processed foods.[73]

Due to the exclusion of dairy products from the diet, iodine is more of a nutrient of concern in vegans than in vegetarians. Correspondingly, evidence indicates that among omnivores, vegetarians, and vegans, vegans have the lowest average iodine intake and the highest risk of iodine deficiency.[31][74]

Because plant-based foods are generally poor sources of iodine (unless they contain iodized salt) — with the exception of seaweed,[75] which is not widely consumed outside of Asian cultures — supplementation with iodine is considered a secondary option for vegetarians and vegans in general. However, in vegetarians and vegans who avoid consuming processed foods and seaweed products and don't add iodized salt to their meals, supplemental iodine is a primary option.

Warnings about iodine

Excessive iodine intake can result in thyroid autoimmunity or goiter and hypothyroidism or hyperthyroidism associated with these phenomena.[76] For adults, the recommended upper intake levels for iodine are between 600 and 1,100 micrograms (µg) per day, depending on the particular guidelines.

How to take *iodine*

The recommended daily intake for iodine is 150 µg for adults (250 µg per pregnant individuals),[77] so the dose of supplementation should not exceed this amount unless authorized by a medical professional.

Recommended Dietary Allowance (RDA) for iodine (mcg)

AGE	MALE	FEMALE	PREGNANT	LACTATING
0–6 months	110*	110*	—	—
7–12 months	130*	130*	—	—

AGE	MALE	FEMALE	PREGNANT	LACTATING
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

Seaweed-based iodine supplements are one relatively effective option to improve iodine status, but this source has been shown to have inferior bioavailability compared to that of potassium iodide.[78][79]

The iodine content of seaweeds varies greatly, even within a same species, from less than 100 µg per gram of seaweed to more than 8,000 µg per gram — a highly unsafe amount. Do not regularly consume high amounts of iodine-rich sea vegetables, such as paddle weed, oarweed, or kelp/kombu. Similarly, high amounts of iodine-rich sea vegetables in supplemental form should be avoided.

Protein

What makes *protein* a secondary option

Readers should refer to our Optimal Protein Intake Guide in the section on Vegetarians & Vegans

Vitamin D

What makes *vitamin D* a secondary option

Vitamin D is a fat-soluble nutrient. It affects a wide range of physiological processes[80] because it exerts its effects by binding to and activating vitamin D receptors, which are distributed throughout the body. Most notably, adequate vitamin D levels are critical for bone health because vitamin D regulates blood calcium levels. Vitamin D is also involved in cell growth, immune function, neuromuscular function, and glucose metabolism. It also has antioxidant and anti-inflammatory properties.

The skin synthesizes vitamin D in response to sunlight exposure. In the context of dietary sources, vitamin D is only naturally present in a few foods, such as eggs and oily fish. The main dietary sources of vitamin D tend to be fortified foods, including milk, milk alternatives, orange juice, and breakfast cereals.

Vitamin D is a nutrient of concern in general; vegetarians and vegans are not at a notably higher risk of

inadequate vitamin D levels than omnivores. Evidence suggests that more than 90% of adults in the United States, Canada, and Mexico do not meet the recommended intake for vitamin D.[81][82][83] Supplemental vitamin D intake was not included in these estimates, but when it was taken into account, the prevalence of suboptimal intake in U.S. adults dropped to 59% and 66% in women and men, respectively.[82]

Depending on the geographical region, the prevalence of inadequate vitamin D levels has been estimated to range from approximately 24% to 49%,[84] with some studies in European countries reporting a prevalence of more than 50%.[85] Notably, the risk of inadequate vitamin D levels is increased in older adults and people with darker skin, as well as during periods when sunlight exposure is limited.

Because inadequate vitamin D levels are relatively common and because vegans and vegetarians don't consume foods naturally rich in vitamin D (like fish), supplemental vitamin D is categorized as a secondary option. Vegetarians and vegans who have limited sunlight exposure and/or consume a diet with little-to-no foods fortified with vitamin D should consider supplemental vitamin D as a primary option.

Warnings about *vitamin D*

Vitamin D is a fat-soluble vitamin that can accumulate to toxic levels with prolonged excessive intake. Vitamin D toxicity, also called hypervitaminosis D, results in hypercalcemia (high blood calcium) and a host of symptoms including nausea, muscle weakness, loss of appetite, thirst, and excessive urination, to give an incomplete list. It can also lead to kidney stones, irregular heartbeat, and sometimes renal failure.

Because vitamin D production in the skin is self-limiting, sun exposure is unlikely to produce vitamin D levels that cause harm (although it may be possible for people with constant, high-level sun exposure (e.g., lifeguards) to synthesize harmfully high levels of vitamin D.[86] However, vitamin D levels in the blood can readily reach toxic levels with chronic, high-level supplementation.

Although ultra-high-level supplementation is universally considered to be toxic, there's some debate on what constitutes the upper limit for safe, "moderate-level" supplementation. Taking approximately 4,000 IU (100 µg) of vitamin D per day for extended periods (≥6 months) seems to increase the risk of hypercalcemia and, among older adults, the likelihood of experiencing a fall.[87]

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

AGE/SITUATION	DOSE (IU)
0–6 months	1,000
7–12 months	1,500
4–8 years	2,500
9–13 years	3,000
14–18 years	4,000
>18 years	4,000
Pregnant and breastfeeding	4,000

Exceeding these limits won't necessarily lead to vitamin D toxicity, and higher doses have been shown to be safe in the short term, without increasing calcium levels to a harmful degree.[88] However, in the long term, especially without frequent vitamin D testing, it is unwise to exceed the amount of vitamin D needed for healthy bodily functions because it all ultimately comes down to vitamin D status, and people with already sufficient levels may be especially at risk of overdoing it.

There are some studies that suggest an increase in falls for older adult participants who are taking vitamin D supplements in doses greater than 1,000 IU per day.[89][90][91] It's currently unclear why this happens or whether it might be mitigated by other fat-soluble vitamins such as K and A, so caution is warranted.

Anyone who takes a multivitamin should check whether it contains vitamin D. It may already contain sufficient amounts for a person's needs. Check the calcium dose as well to ensure it is not too high.

A genetic mutation in the CYP24A1 gene can cause idiopathic infantile hypercalcemia.[92] This condition, usually identified in childhood, causes high levels of calcium in the blood and urine and leads to calcium deposits in the kidneys. This mutation can lead to vitamin D toxicity with daily intakes as low as 500 IU (12.5 µg).

Vitamin D supplements have the potential for interactions with certain medications. Some examples of medications are included below. *Because the following is not a comprehensive list, it is important to discuss vitamin D supplementation with a healthcare provider when taking any prescription medications.*[93]

- *Orlistat* (also known as Xenical and Alli). These weight loss drugs may reduce vitamin D absorption from the diet and supplements.[94]
- *Statins.* Statin drugs reduce cholesterol synthesis in the body. High levels of vitamin D supplementation can potentially reduce the cholesterol-lowering ability of statin drugs by binding to and competing with a common statin-binding enzyme.[95]
- *Corticosteroid medications,* such as prednisone. Corticosteroids reduce vitamin D metabolism, and vitamin D deficiencies were reported to occur with 2x higher frequency in people taking oral corticosteroids compared to non-users.[96]
- *Thiazide diuretics.* Diuretics are drugs that promote water loss in the body. Because thiazides decrease calcium loss through urine, and vitamin D increases calcium absorption, taking vitamin D supplements alongside thiazides can potentially lead to dangerously high calcium levels (hypercalcemia).[97][98]

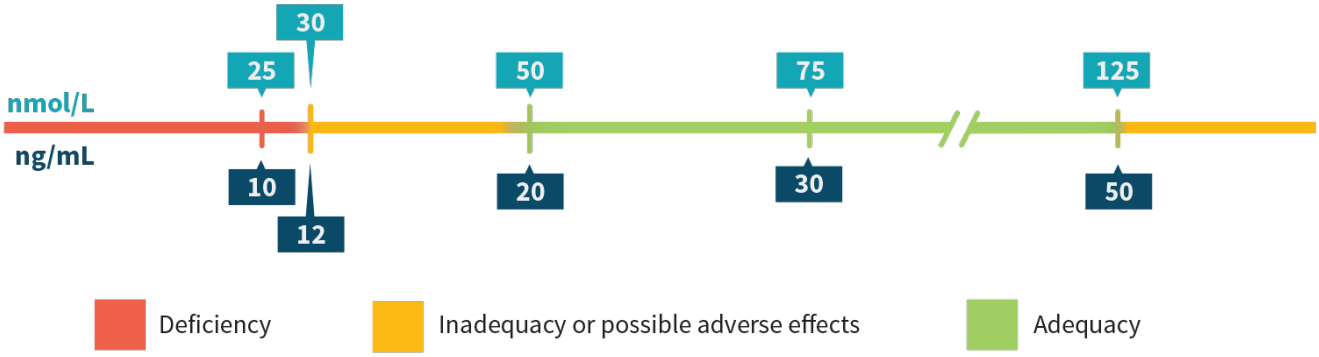
How to take *vitamin D*

The Recommended Dietary Allowance for vitamin D is 400 to 800 IU, but this may be insufficient for some people to achieve and maintain adequate vitamin D levels. For moderate supplementation, some researchers recommend a daily dose of 2,000 IU for most people.[99]

Vitamin D3 is recommended over vitamin D2 because it's more effective for raising blood vitamin D levels. Additionally, vitamin D should be taken with food, particularly a source of fat.[100][101]

It may be helpful to determine whether supplemental vitamin D is really needed by checking current vitamin D levels via a blood test — specifically levels of 25-hydroxyvitamin D (25(OH)D).

Serum 25(OH)D concentrations



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)

In case of *deficiency*, a medically supervised intervention is needed. *Do not begin any intervention without discussing it with a physician.* Common medical interventions include taking 50,000 IU (1,250 µg) of vitamin D2 or D3 at least 3 times per week for 6 to 8 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 to 1,000 IU (20–25 µg) is commonly used for maintenance.

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

In case of *adequate* vitamin D levels, a vitamin D supplement may not be necessary, especially for people who spend a lot of time outside and live near the equator. However, taking 400 to 600 IU (10–15 µg) of vitamin D3 per day may help maintain vitamin D levels in the adequate range, particularly during the colder, darker months, when the body is 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.

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 if a person's BMI is over 30[102] or if they have poor vitamin D absorption or processing (due to a problem with the kidneys, liver, or gastrointestinal tract), an alternative is to switch to 1,000 to 2,000 IU (25–50 µg) of vitamin D3 per day.

Because vitamin D is fat-soluble, it is better absorbed when it is taken with a fat-containing food or supplement (e.g., fish oil).

Promising Supplements

Zinc

What makes *zinc* a promising option

Zinc is an essential mineral and is a component of more than 300 enzymes in the body. Accordingly, zinc has various biological roles — it is important for immune health, sexual health, brain function, and glycemic control.[103][104] It's also involved in the regulation of gene expression and has anti-inflammatory and antioxidant properties.[103][104]

Oysters contain substantially more zinc than any other food, but beef and poultry typically provide the majority of zinc in the Western diet. Additionally, although some plant foods (e.g., legumes, nuts and seeds) contain a moderate amount of zinc, they also contain phytate (the storage form of phosphorus in plants), which reduces the bioavailability of zinc.[105]

Unsurprisingly, dietary zinc intake and serum zinc levels are generally lower in vegetarians and vegans than in omnivores.[106] There's also limited evidence to suggest that vegans are at a higher risk of zinc deficiency than vegetarians and omnivores.[31]

Nonetheless, serum zinc levels tend to still be within the normal range in vegetarians and vegans in developed countries,[107][108] and there's a lack of evidence that indicates adverse health consequences in adult vegetarians and vegans that are attributable to lower zinc status.[109]

This is due to homeostatic mechanisms that work to maintain zinc status within an adequate range. For instance, in response to a low-zinc diet, dietary zinc absorption is increased and gastrointestinal zinc excretion is decreased.[109] However, evidence suggests that an upregulation of zinc absorption from the consumption of a low-zinc diet is inhibited if the diet is also high in phytate.[110]

As a countermeasure, food-processing techniques can help to reduce phytate in plant foods. For example, soaking cereals and legumes in water for a few hours decreases the phytate content.[111] Cooking at high heat, milling (i.e., pounding grains into a flour), and fermentation can also help.[112][113] Additionally, the phytate content of some plant foods degrades during storage.[111]

Given the inhibitory effect of phytate on zinc absorption and the likelihood of a diet with a high phytate to zinc ratio, it's estimated that dietary zinc requirements may be as much as 50% greater in strict vegetarians and vegans.[114] For this reason, in addition to the fact that there is no storage site for zinc in the body,[115] and thus an adequate daily intake is crucial, supplemental zinc is considered a promising option, particularly for vegans.

Warnings about *zinc*

Zinc is considered safe for adults in amounts less than 40 mg per day.[116] When this level of intake is exceeded, nausea, vomiting, stomach cramps, and even diarrhea can occur.[116]

Effects of low, adequate, and high zinc intake

At the same time, insufficient zinc intake can also cause gastrointestinal issues; it's all about balance. If too much zinc is taken — generally, more than 100 mg — for a long period of time, it can also decrease levels of copper, an important mineral needed for iron absorption and red blood cell formation.[117] Chronic zinc consumption or very high doses over a short period may also decrease the immune response[118] and reduce levels of HDL-C.[116] Zinc can also interact with quinolone and tetracycline antibiotics such as ciprofloxacin and doxycycline.[119][120] Taking zinc along with these antibiotics can reduce the amount of each that is absorbed. To reduce this effect, the antibiotic should be taken at least 2 hours before or 4 to 6 hours after zinc.[121][122] Other medicines, such as chlorthalidone and hydrochlorothiazide, can increase the amount of zinc in urine, so taking these thiazide diuretics could decrease the amount of zinc in the body.[123] Knowing what dietary supplements a person takes is important for doctors and pharmacists so that they can check for any interactions.

(ULs) of Zinc in Milligrams

AGE	MALE OR FEMALE (including pregnant or lactating women)
0–6 months	4
7–12 months	5
1–3 years	7
4–8 years	12
9–13 years	23
14–18 years	34
>18 years	40

Reference: Zinc[116]

How to take *zinc*

The recommended dietary intake for zinc is 11 milligrams per day for men and 8 milligrams per day for women. Vegans, as well as vegetarians whose habitual diet has a high phytate-to-zinc ratio, may benefit from daily supplementation with a low dose of zinc (approximately 5 to 10 milligrams).

High supplemental doses of zinc (more than 40 milligrams per day) should be avoided because they can cause gastrointestinal symptoms in the short term, and long-term use can interfere with copper absorption and immune function.[114]

Zinc supplements vary in the form of zinc they contain. Whether there is a best form of zinc remains to be determined, but evidence suggests that zinc gluconate, zinc aspartate, and zinc citrate all have pretty good bioavailability.[124][125][126] For more information of how much elemental zinc each zinc form contains, see the zinc page.

Creatine

What makes *creatine* a promising option

Creatine is a molecule that is made primarily in the liver from the amino acids arginine, glycine, and methionine. The vast majority (>95%) of creatine is stored in skeletal muscle, but it's also stored in the brain.[127] Creatine is most notably involved in energy production, particularly during brief, high-intensity exercise and strenuous mental activity.

Dietary creatine is only present in animal products (mainly meat), and therefore vegans and vegetarians consume little-to-no creatine. Creatine is potentially a nutrient of concern because creatine deficiency syndromes are characterized by neurological symptoms (e.g., intellectual disability, seizures),[128] and low brain creatine content is present in several neurological conditions.[129]

However, although creatine levels in the blood and skeletal muscle have been shown to be lower in vegans/vegetarians than in omnivores,[130] there's an absence of evidence to indicate that consuming a vegan or vegetarian diet leads to inadequate brain creatine content. In fact, studies that evaluated brain creatine content have not found differences between vegans/vegetarians and omnivores.[131][132] Furthermore, limited evidence indicates that rates of neurological disease do not differ between vegans/vegetarians and omnivores.[133] It's even plausible that a vegan or vegetarian diet can reduce the risk of cognitive impairment,[134] but more evidence is needed.

These findings are likely related to the fact that the brain mainly relies on endogenous creatine synthesis to meet its needs, and thus dietary creatine doesn't have much of an effect on brain creatine content, unless brain creatine content is inadequate.[127]

All in all, despite consuming little-to-no creatine, vegetarians and vegans seem to be able to produce enough creatine endogenously to support general health. As such, supplemental creatine isn't essential like vitamin B12.

Nonetheless, that doesn't mean that supplementation with creatine isn't beneficial in vegans and vegetarians; it's apparent that supplementing with creatine can help to optimize certain outcomes.

Generally speaking, supplementing with creatine improves measures of anaerobic exercise performance[135][136] and can enhance resistance exercise-induced gains in strength and muscle mass to a small degree.[137][138][139] Additionally, supplementing with creatine may improve memory, especially in older adults.[140][141] Creatine may also be particularly effective for improving cognitive function in situations of increased stress (e.g., sleep deprivation, mental fatigue, hypoxia).[127]

Because vegans and vegetarians have lower blood and muscle creatine levels than omnivores, they experience a greater increase in creatine levels from supplementation,[131][130] and so they theoretically have more to gain from supplementing with creatine in the context of exercise performance. The limited evidence available does not clearly support this hypothesis,[130] but further research is needed before being able to draw strong conclusions.

In the context of cognitive function, a 2023 crossover trial that had vegetarians and omnivores supplement with creatine daily for 5 weeks reported a similar response between populations.[142] In a 5-day randomized controlled trial published in 2011, after supplementing with creatine, memory (but not other measures of cognitive function) was better in vegans/vegetarians than in omnivores.[143] However, this result was due to a decrease in memory from baseline in the omnivores, as opposed to an improvement in the vegans/vegetarians, so it's difficult to say whether the vegetarians/vegans had a better response to creatine. It's possible that the results can be explained by outside factors that caused a worsening of memory performance in the omnivores. One other study in 2003 found an improvement in memory and a reduction in mental fatigue for vegans and vegetarians, though there was no comparison to omnivores.[144]

Collectively, the available evidence does not indicate that vegans/vegetarians derive a greater benefit from supplemental creatine than omnivores.

To conclude, vegans and vegetarians have lower blood and muscle levels of creatine than omnivores, but there's an absence of evidence indicating that this contributes to ill effects on health or increases the risk of chronic diseases. For this reason, supplemental creatine isn't a primary option, but it is considered a promising option because it can improve certain outcomes to a small degree, which may be practically meaningful to some vegans and vegetarians. These include power output, strength, muscle mass, memory, and possibly other measures of cognitive function, particularly in situations of increased stress.

Warnings about *creatine*

Decades of research have demonstrated that creatine is generally well tolerated. The only recorded adverse effects are nausea, diarrhea, and stomach cramps in people who were taking more than 10 grams at once, and even at such high doses, these effects are rare.[145][146] Still, a person who is particularly sensitive to creatine's digestive side effects should split the daily dose, take it with some food, and drink more fluids. Another alternative is *micronized* creatine monohydrate, which dissolves more easily in liquids.

Concerns about creatine supplementation can be divided into 3 main categories: kidney function, muscle function, and thermoregulation.

Both blood and urinary creatinine may be increased by supplementing with creatine, which has led to the hypothesis that if the kidneys are forced to excrete higher-than-normal levels of creatine or creatinine, some sort of damage and impairment in function will eventually take place.[147] In support of this hypothesis, evidence from some rodent studies showed that creatine may negatively affect kidney function.[148][149]

However, animals respond differently than humans to creatine ingestion,[150] and in people without known health conditions, supplementing with up to 10 grams of creatine per day for 10 months to 5 years has not

been shown to adversely affect kidney function.[151][152] Moreover, one study in participants with type 2 diabetes and one study in participants with peripheral artery disease (two populations at an increased risk of chronic kidney disease) found that daily creatine supplementation for 8 to 12 weeks did not affect markers of kidney function.[153][154] These results may not be generalizable to other populations (i.e., other disease states), but they do provide further evidence against the postulated link between creatine supplementation and kidney function.

The rationale behind the claim that creatine supplementation causes dehydration and muscle cramping is based on creatine's ability to drive water into cells. It's postulated that creatine preferentially increases intracellular water uptake and retention[155] and that the bound intracellular water might not be released into the extracellular compartment for thermoregulation during exercise, leading to muscle cramping, dehydration, electrolyte imbalances, and other heat-related issues.[156] However, there is no scientific evidence to support these claims.[156] Several trials have investigated the effects of creatine supplementation on muscle cramps, muscle tightness, muscle strains, injuries, and missed practices, and the results have suggested that creatine use may reduce the likelihood of muscle injury and dysfunction compared to nonuse of creatine.[157][158] In the clinical setting, creatine supplementation has been shown to decrease the incidence of muscle cramps during hemodialysis treatment by 60%.[159]

Out of caution, people who are taking medications that can increase the risk of harm or damage to the kidneys (i.e., nephrotoxic drugs) may want to skip creatine supplementation.

Supplementation with creatine typically results in weight gain, partly due to an increase in total body water.[160] The range of weight gain after a creatine loading phase tends to fall between 0.9 and 1.8 kg (1.98–3.96 lbs).[161][162] This may be of particular concern to individuals competing in weight-sensitive sports.

Supplementation with creatine has been reported to negatively affect aerobic capacity to a small degree.[163] It has been speculated that this potential detrimental effect may be related to increases in total body water and body weight following supplementation with creatine.[164]

🔍 Digging Deeper: ATP and muscular contractions

Adenosine triphosphate (ATP) can be viewed as the body's main energy source. Carbohydrates, fats, proteins, and ketones are technically not directly used as energy but are rather used to make a certain amount of ATP that the body can then use to perform an action, like contracting a muscle.

For a muscle contraction to occur, the brain sends an electrical signal to the muscle that tells a calcium reserve, called the sarcoplasmic reticulum, to release calcium into the muscle. The calcium is necessary for the ATP to do its job, allowing the muscle to contract. Conversely, ATP is necessary for the calcium to be pumped back into the sarcoplasmic reticulum in preparation for a future muscle contraction.

🔍 Digging Deeper: Creatine and testosterone

You may have heard that creatine can raise testosterone, the precursor to *dihydrotestosterone* (DHT), and can thereby accelerate or cause hair loss. To date, though, the overall body of evidence suggests that creatine doesn't affect testosterone or hair loss.[165][166][167][168][169][170][171][172][173][174][175][176]

Creatine can cause water retention, which may notably increase body weight. Avoiding high-dose creatine loading and cosupplementation with carbohydrates to augment PCr increases and glycogen storage can limit the transient dreaded "bloating" to a minimum.[177][178][179] This side effect is largely harmless and is reversed when creatine supplementation is stopped. Theoretically, this water retention could harm people whose kidney disorders are being treated with diuretics, which cause water loss.[145] This possible harm is based on known mechanisms rather than human trial data.

Adenosine triphosphate (ATP) can be viewed as the body's main energy source. Carbohydrates, fats, proteins, and ketones are technically not directly used as energy but are rather used to make a certain amount of ATP that the body can then use to perform an action, like contracting a muscle.

For a muscle contraction to occur, the brain sends an electrical signal to the muscle that tells a calcium reserve, called the sarcoplasmic reticulum, to release calcium into the muscle. The calcium is necessary for the ATP to do its job, allowing the muscle to contract. Conversely, ATP is necessary for the calcium to be pumped back into the sarcoplasmic reticulum in preparation for a future muscle contraction.

🔍 **Digging Deeper: Creatine and testosterone**

You may have heard that creatine can https://examine.com/nutrition/creatine-testosterone/](raise testosterone), the precursor to dihydrotestosterone (https://examine.com/topics/dht/), and can thereby accelerate or cause [https://examine.com/nutrition/does-creatine-cause-hairloss/](hair loss). To date, though, the overall body of evidence suggests that creatine doesn't affect testosterone or hair loss.[reference[166][167][168][169][170][171][172][173][174][175][176]

Creatine can cause water retention, which may notably increase body weight. Avoiding high-dose creatine loading and cosupplementation with carbohydrates to augment phosphocreatine increases and glycogen storage can limit the transient dreaded "bloating" to a minimum.[177][178][179] This side effect is largely harmless and is reversed when creatine supplementation is stopped. Theoretically, this water retention could harm people whose kidney disorders are being treated with diuretics, which cause water loss.[145] This possible harm is based on known mechanisms rather than human trial evidence.

How to take *creatine*

Vegetarians and vegans interested in supplementing with creatine should take approximately 3 to 5 grams per day. There's currently insufficient evidence to support the idea that higher doses are better for some outcomes.

Omega-3 Fatty Acids

What makes *omega-3 fatty acids* a promising option

Omega-3 fatty acids (omega-3s) are essential polyunsaturated fatty acids, meaning that they must be obtained in the diet; otherwise, certain adverse health outcomes arise.[180] Omega-3s have wide-ranging effects in the body. Most notably, they contribute to the structure of cell membranes, especially in the brain and retina.

The discussion of omega-3s mainly revolves around *alpha-linolenic acid* (ALA), *docosahexaenoic acid* (DHA), and *eicosapentaenoic acid* (EPA). Animal-based foods (particularly fish) are the primary sources of EPA and DHA in the diet, and ALA is obtained from plant-based foods, including vegetable oils (e.g., canola oil), seeds (e.g., flaxseed, chia seeds), and walnuts.

ALA is the only truly essential omega-3 because it cannot be synthesized by the body, unlike the other omega-3s. Once ingested, there are a few different ways that the body uses ALA, including to make EPA and DHA.[181] As such, to cover the minimum amount of omega-3s needed for general health, consuming animal-based foods containing pre-formed EPA and DHA is not necessary because a diet containing an adequate amount of ALA is sufficient. The adequate intakes for ALA are set at 1.1 and 1.6 grams per day for women and men, respectively,[180] although higher intakes in the range of 2 to 4 grams per day are thought to be closer to optimal.[182]

The conversion rate of ALA to EPA in the body is poor, and the conversion rate of ALA to DHA is even worse.[181] Studies that had participants supplement with ALA for the purpose of increasing blood levels of EPA and DHA have reported modest increases in EPA, with little-to-no change in the level of DHA.[181] This is a potential concern because higher blood levels of EPA and DHA are associated with improved health outcomes, including a reduced risk of type 2 diabetes,[183] chronic kidney disease,[184] colorectal cancer,[185] and cognitive decline and dementia.[186][187][188] Higher blood levels of EPA and DHA are also associated with a reduced risk of all-cause mortality,[189] as well as a reduced risk of death caused by cardiovascular disease or cancer.[189]

Vegans and vegetarians have lower intakes of EPA and DHA than omnivores, but they typically have higher ALA intakes.[31][190] Moreover, vegans and vegetarians generally have lower blood levels of EPA and DHA than omnivores,[31][190] but the difference isn't as large as might be predicted, which is thought to be due to adaptive mechanisms in the body, such as increased production of DHA from ALA in the liver.[133]

Despite vegans and vegetarians generally having lower blood levels of EPA and DHA than omnivores, consuming a vegan or vegetarian diet is associated with a reduced risk of chronic diseases like cardiovascular disease and type 2 diabetes.[191][192] Also, neurological disease rates seem to be similar between vegans and vegetarians and omnivores,[133] but further research is needed in this area.

Based on the available evidence, increasing blood levels of EPA and DHA in vegans and vegetarians could

theoretically further reduce the risk of chronic diseases, but ultimately, direct research is needed to determine whether this is the case. As such, although supplementing with omega-3s is likely beneficial in vegans and vegetarians — that is, supplementation could optimize health outcomes — it's not a necessity. There's an absence of evidence indicating that vegans and vegetarians are at an increased risk of adverse health outcomes due to their diets containing little-to-no EPA and DHA. For these reasons, omega-3s are considered a promising option.

Warnings about *omega-3 fatty acids*

Fish oil is known to cause gastrointestinal side effects, including abdominal pain and diarrhea, in some people.[193][194] Taking fish oil with food may help avoid these unwanted side effects.[195]

Although it is rare, some cases suggest that fish oil interacts with anticoagulant medications like warfarin/Coumadin/Jantoven and antiplatelet medications like aspirin and can increase the risk of bleeding when used together.[196][197][198], especially at daily doses above 1 gram.[199] Taking fish oil alone does not appear to have this risk.[200][201] Consult with a prescriber or medical professional before taking fish oil with any of these medications.

🔍 **Digging Deeper: Oxidized fish oil**

Fish oil can become rancid and oxidize when exposed to oxygen, heat, or light. These types of oil 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)

PV is a measure of primary oxidation products (peroxides), and AV is 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.

Oxidation of fish oils may be more common than many suspect. One 2015 study found that nearly 50% of commercial fish oils exceeded the maximum recommended TOTOX value,[202] whereas others found good compliance with TOTOX limits.[203][204] Taken together, these divergent results demonstrate just how widely the quality of commercially available fish oil supplements can vary.

Evidence for the health effects of consuming oxidized fish oils is a bit mixed. For healthy individuals, 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 7 weeks of supplementation with oxidized fish oil.[205]

However, in participants with high levels of cholesterol and triglycerides, consumption of highly oxidized fish oils can minimize its efficiency in improving metabolic markers such as fasting glucose, total cholesterol, and triglycerides.[206]

There is some evidence of fish oil increasing the risk of atrial fibrillation, as detailed elsewhere by Examine.

The risk seems to be present even at dosages as low as 1 gram per day and may be greater with EPA-only supplements than with combined EPA and DHA supplements.[207] There are still many uncertainties, including the magnitude of risk and whether or not this risk is present in people without cardiovascular disease or who are not at a high risk of cardiovascular disease.

Although DHA is marginally better than EPA at reducing triglyceride levels, it can cause a modest increase in low-density lipoprotein (LDL-C, the "bad cholesterol").[208]

How to take *omega-3 fatty acids*

Vegans and vegetarians who are interested in increasing their blood levels of omega-3s should supplement with algal oil (made from marine algae), which is an equally effective alternative to fish oil.[209] For general health purposes, supplementing with 250 mg of omega-3s (in an approximately 2 to 1 ratio of DHA to EPA) has been shown to significantly increase blood levels of omega-3s.[210]

An omega-3 index (i.e., the amount of EPA and DHA in red blood cells) of at least 8% is often touted as being optimal for health, particularly for protection from cardiovascular disease.[192] Although it remains to be determined whether maintaining such a high omega-3 index improves health outcomes in vegetarians and vegans, it typically requires supplementing with at least 1,000 milligrams of total omega-3s daily to achieve an omega-3 index of at least 8%.[211]

Unproven Supplements

Carnitine

What makes *carnitine* an unproven supplement

L-carnitine, the biologically active form of carnitine (which we'll simply refer to as "carnitine" from here on), is a naturally occurring compound found in all mammalian species. It plays a crucial role in the body's energy metabolism, especially in tissues that derive much of their energy from fatty acid oxidation, such as the heart and skeletal muscles.[212]

Although the body can synthesize carnitine out of lysine and methionine, approximately 75% of the carnitine in people who are omnivorous comes from the diet, and the main dietary sources are meat (primarily red meat), fish, eggs, and dairy.[213]

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 [https://ods.od.nih.gov/factsheets/Carnitine-HealthProfessional/#h3](Carnitine: Fact Sheet for Health Professionals). NIH ODS. Last updated October 10, 2017; accessed October 27, 2019

Carnitine deficiency can result in impaired entry of fatty acids into the mitochondria, disrupting the breakdown of fats for energy and ultimately leading to heart disease, brain disorders, muscle weakness, and even death.[214]

Compared to omnivores, vegetarians and vegans tend to have lower plasma/serum levels of carnitine,[215][216][217][218] although this is not always the case.[219][220] Importantly, however, even when vegetarian/vegan diets result in lower levels of carnitine, these levels tend to remain within the normal physiological range. This may be (at least partly) explained by (i) greater bioavailability of dietary carnitine in individuals who are adapted to low-carnitine diets (66% to 86% of available carnitine) than in individuals adapted to high-carnitine diets (54% to 72% of available carnitine),[221] (ii) adaptations that increase the uptake of carnitine in cells,[222] and (iii) more efficient renal reabsorption of carnitine.[217]

It's also worth noting that in one trial, despite lower plasma carnitine levels in vegetarians compared to

omnivores, muscle carnitine levels remained similar between groups, and supplementation with L-carnitine had no effect on muscle function or energy metabolism.[218]

Keeping in mind that vegetarian/vegan diets tend to result in lower plasma/serum levels of carnitine but don't generally tend to result in carnitine deficiency and that there's no evidence from randomized controlled trials to suggest a benefit of supplementation with carnitine in vegetarians/vegans, carnitine can only rank as an unproven supplement.

Beta-alanine

What makes *beta-alanine* an unproven supplement

Beta-alanine is a nonessential amino acid that can be synthesized in the liver from polyamines, pyrimidines, and coenzyme A. The majority of beta-alanine is still obtained from dietary sources and supplements,[223] with the primary source being the overall diet. With animal products, including beef, chicken, fish, and poultry (0.2 to 1.0 grams of beta-alanine per 100 grams) as the primary sources, vegetarians and vegans tend to have significantly lower dietary beta-alanine intakes.[224][225]

In addition to its well-known athletic benefits, higher beta-alanine intakes may improve vascular function and general cardiovascular health,[226], reduce cancer growth,[227] protect the brain,[228], and slow aging.[223] Despite the body's ability to produce beta-alanine in the liver, it seems perfectly reasonable to assume that for people who cannot obtain significant amounts of beta-alanine through their diet, such as vegetarians and vegans, supplements could be beneficial[229][230] and perhaps even mandatory for people on low beta-alanine diets.

Beta-alanine (BA) is the primary orally bioavailable precursor of the intracellular H^+ buffer *carnosine* (CAR). The process of carnosine synthesis from BA and L-histidine is thought to be limited primarily by the dietary intake of beta-alanine, with only a minor, if not marginal, contribution from the previously mentioned BA synthesis in the liver.[225][231] Therefore, it seems that BA supplementation in vegans and vegetarians could improve athletic performance at peak oxygen consumption,[232] Currently, hard empirical evidence doesn't support the conclusion that vegetarians and vegans need to supplement with beta-alanine.

What is missing is clear evidence of a health-relevant reduction in carnosine levels on low beta-alanine diets. In a 6-month study, for example, scientists found that switching 40 omnivorous women to a vegetarian diet did not, as one might suspect, lead to a progressive reduction in carnosine levels in muscle biopsies that were collected quarterly.[220] These findings are corroborated by the recently reported lack of association between dietary beta-alanine intake and intracellular H^+ buffer levels in 60 active omnivorous men and women without apparent health conditions.[233]

So how can these results be reconciled with the observational data from the 12 vegetarian or vegan participants in a 2010 cross-sectional study? The study reported 17% to 26% lower carnosine levels in vegans/vegetarians compared to their omnivore counterparts,[225] a finding that seems consistent with the recently reported lack of association between dietary beta-alanine intake and muscle carnosine levels in the 60 active omnivorous men and women mentioned previously.[233]

The reason for the contradictory study results may be as simple as "time" — time spent on a low beta-alanine diet. With a duration of "only" 6 months, the previously cited dietary intervention in 40 formerly

omnivorous women[220] may simply have been too short to cause a significant change in muscular carnosine levels in its participants. In contrast, the 12 male vegetarians in the 2010 cross-sectional study had been following a lacto-ovo vegetarian or vegan diet for an average of 9.5 years (minimum of 5 years) when their muscle carnosine levels were measured[225] — which is enough time, one could argue, for a trend toward decreasing carnosine levels to become observable in the form of a statistically significant difference.

An as yet unproven hypothesis on the usefulness of beta-alanine supplements for vegetarians and vegans is that our ability to endogenously produce beta-alanine via pyrimidine catabolism in the liver slows or eliminates the development of full-blown deficiency states, even in vegetarians who can obtain the necessary building blocks for BA synthesis from whole grains and legumes, as well as certain vegetables such as asparagus, cauliflower, spinach, mushrooms, and green peas.[234][223] In the short term, this could compensate for a less than optimal beta-alanine intake. However, over the course of several years, the body's endogenous supply chain may eventually become overwhelmed, and the intramuscular carnosine levels of long-term nonpescetarian vegetarians and vegans may gradually decline.

However, even if this hypothesis is correct, there is currently no convincing evidence for the existence of such a thing as a "beta-alanine deficiency" in vegetarians or vegans. Therefore, based on current evidence, beta-alanine does not meet the criteria for a recommended (let alone mandatory) supplement for the average vegetarian or vegan.

For individuals who are seeking an athletic edge, the situation may be slightly different. If they want to benefit from the proven ergogenic effects of increasing their carnosine stores, vegetarians, vegans, and omnivores alike will need to supplement their dietary BA intake with approximately 3 to 5 grams of the carnosine precursor per day to achieve a 30% to 50% increase in the performance-enhancing, acid-buffering effects.[235] What remains to be seen, however, is whether the washout time (i.e., the time it takes for the elevated carnosine levels to return to normal when supplementation is stopped) and the proposed maintenance dose of approximately 1.2 grams per day differ among vegetarians, vegans, and omnivores or whether the previously reported 9-week washout time with an average reduction of approximately 2% per week applies to everyone,[236][237] regardless of their individual BA intake.

Iron

What makes *iron* an unproven option

Iron is an essential mineral and a component of a number of proteins and enzymes that support critical biological functions.[238] Most notably, iron is a component of hemoglobin, a protein in red blood cells that transfers oxygen from the lungs to the rest of the body, and myoglobin, a protein that stores and transports oxygen in muscle cells.[239]

Dietary iron comes in two forms: heme and nonheme iron. Heme iron is the more easily absorbed form. Animal products (i.e., meat, fish, and poultry) contain heme iron and nonheme iron, whereas plant-based foods contain only nonheme iron. Because the diets of vegans and only contain the less bioavailable nonheme iron, iron is considered a nutrient of concern in these populations.

However, the available evidence indicates that iron intake does not significantly differ among vegans, vegetarians, and omnivores, even when accounting for the lower bioavailability of iron in plant-based foods.[31] With respect to iron status as measured by serum ferritin levels, values are generally lower in vegans and vegetarians than in omnivores.[240] Nevertheless, the average serum ferritin level in vegans and

vegetarians is still within the normal range.[31][241] Additionally, the prevalence of inadequate serum ferritin levels or iron deficiency anemia isn't all that different between populations,[240][108] although there is evidence to suggest that the risk of having inadequate levels is slightly higher in vegans and vegetarians.[31][240]

There are various reasons for why iron status doesn't substantially differ among vegans and vegetarians and omnivores. First and foremost, body iron status is the primary determinant of iron absorption,[242][243] In the context of low iron status, nonheme iron is absorbed nearly as well as heme iron.[108] Additionally, evidence suggests that the body adapts to a diet with low iron bioavailability over time by increasing the absorption of nonheme iron and decreasing the fecal excretion of iron.[244][245] Similarly, evidence suggests that the inhibitory effect of phytate (which is found in legumes, nuts, and whole grains) on iron absorption seems to decrease over time.[246]

Notably, higher body iron status isn't necessarily a good thing. In fact, higher serum ferritin levels have been associated with an increased risk of type 2 diabetes,[247] including in a Mendelian randomization study.[248]

In excessive amounts, iron is toxic to cells because it acts as a pro-oxidant and generates reactive oxygen species.[249] Pancreatic beta-cells, which are responsible for producing and secreting insulin, are particularly susceptible to the consequences of excess iron due to their proclivity to take up iron and their low content of antioxidant enzymes.[250][251][252]

All in all, although vegans and vegetarians typically have lower serum ferritin levels than omnivores, the average level is still within the normal range. Because elevations in markers of body iron status are associated with an increased risk of chronic diseases, and there are risks to supplementing with iron (e.g., gastrointestinal symptoms like nausea and constipation), supplementation is not recommended for vegans and vegetarians, unless it's prescribed by a medical practitioner.

In vegans and vegetarians with inadequate body iron status, besides paying closer attention to dietary sources of iron to ensure an adequate intake, other dietary strategies can be used to enhance iron absorption. These strategies include consuming iron-rich foods with vitamin C (either a supplement or vitamin-C-rich foods) and consuming iron-rich foods separately from major sources of calcium and polyphenols (e.g., tea).[253]

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.[254]

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.[255] 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.[256]
- Most studies that looked at protein intake and calcium excretion list dairy products as a protein source,[257] 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[258] and that high protein intake "promotes bone growth and retards bone loss whereas low-protein diet is associated with higher risk of hip fractures."[259] High-protein diets have also been shown to modestly suppress the decrease in bone mineral density caused by weight loss.[260]

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.[261] 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),[262] which promotes notably bone growth.[263]

All in all, current evidence suggests that *protein's effect on bones is either neutral or beneficial*.[261][264]

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.[265]

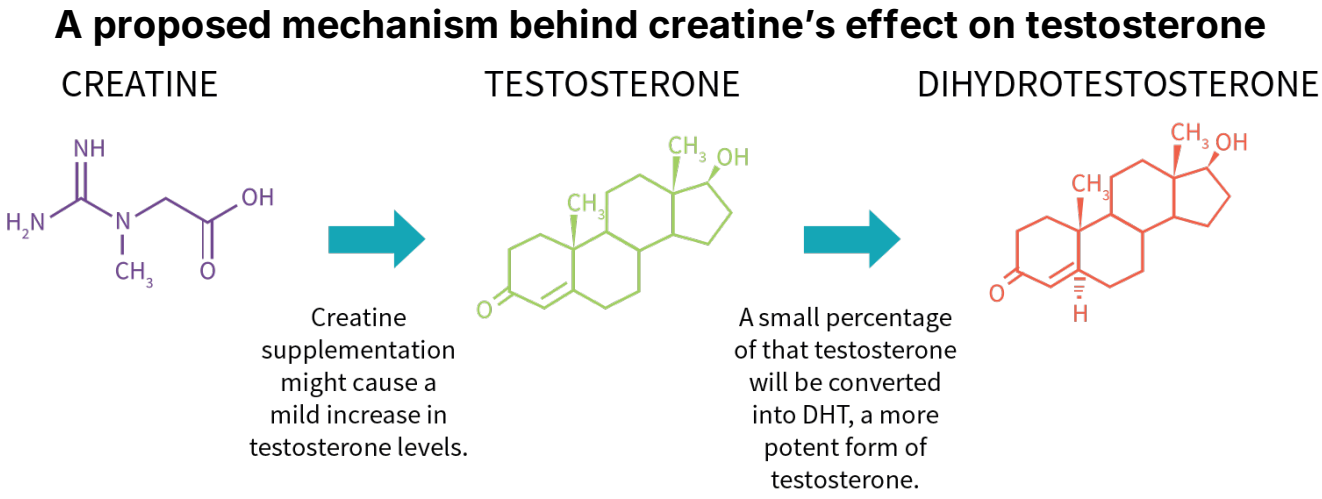
Part of the responsibility for ensuring fish oil remains unoxidized is on the buyer. Exposure of fish oil to light, heat, and oxygen accelerates the oxidation of the oil, with the magnitude of damage depending on the length and degree of exposure. Once you buy the supplement, it is prudent to store it 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.[165] 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.[266][267]

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,[173][174] but 10 saw no effect.[165][167][166][168][169][170][171][175][176][268] 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.[166][167][169][171][176]



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)	↔
	Crowe 2003	28	Male rugby players	25	6 weeks	3 g/day HMB* + 3 g/day creatine	↔

BETWEEN-GROUP EFFECT	STUDY	SAMPLE SIZE	POPULATION	AVG AGE	DURATION	DOSE	EFFECT ON TESTOSTERONE
	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	↔
	Rhimi 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.[269][270][271][272]

** 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, Pavela 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, Raisinger 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. Wu JY, Tso R, Teo HS, Haldar S The utility of algae as sources of high value nutritional ingredients, particularly for

alternative/complementary proteins to improve human health.. *Front Nutr*. (2023)

30. Wells ML, Potin P, Craigie JS, Raven JA, Merchant SS, Helliwell KE, Smith AG, Camire ME, Brawley SH Algae as nutritional and functional food sources: revisiting our understanding.. *J Appl Phycol*. (2017)

31. Nicole Neufingerl, Ans Eilander Nutrient Intake and Status in Adults Consuming Plant-Based Diets Compared to Meat-Eaters: A Systematic Review. *Nutrients*. (2021 Dec 23)

32. Institute of Medicine Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline. *National Academies Press*. (1998)

33. Collin SM, Metcalfe C, Refsum H, Lewis SJ, Zuccolo L, Smith GD, Chen L, Harris R, Davis M, Marsden G, Johnston C, Lane JA, Ebbing M, Bønaa KH, Nygård O, Ueland PM, Grau MV, Baron JA, Donovan JL, Neal DE, Hamdy FC, Smith AD, Martin RM Circulating folate, vitamin B12, homocysteine, vitamin B12 transport proteins, and risk of prostate cancer: a case-control study, systematic review, and meta-analysis.. *Cancer Epidemiol Biomarkers Prev*. (2010-Jun)

34. Brasky TM, White E, Chen CL Long-Term, Supplemental, One-Carbon Metabolism-Related Vitamin B Use in Relation to Lung Cancer Risk in the Vitamins and Lifestyle (VITAL) Cohort. *J Clin Oncol*. (2017 Oct 20)

35. Sun NH, Huang XZ, Wang SB, Li Y, Wang LY, Wang HC, Zhang CW, Zhang C, Liu HP, Wang ZN A dose-response meta-analysis reveals an association between vitamin B12 and colorectal cancer risk.. *Public Health Nutr*. (2016-Jun)

36. Liu K, Yang Z, Lu X, Zheng B, Wu S, Kang J, Sun S, Zhao J The origin of vitamin B12 levels and risk of all-cause, cardiovascular and cancer specific mortality: A systematic review and dose-response meta-analysis.. *Arch Gerontol Geriatr*. (2024-Feb)

37. Wu S, Feng P, Li W, Zhuo S, Lu W, Chen P, Sui Y, Fang S, Yang Z, Ye Y Dietary Folate, Vitamin B6, and Vitamin B12 and Risk of Cardiovascular Diseases among Individuals with Type 2 Diabetes: A Case-Control Study.. *Ann Nutr Metab*. (2023)

38. Allen LH, Miller JW, de Groot L, Rosenberg IH, Smith AD, Refsum H, Raiten DJ Biomarkers of Nutrition for Development (BOND): Vitamin B-12 Review.. *J Nutr*. (2018 Dec 1)

39. Greibe E, Mahalle N, Bhide V, Heegaard CW, Naik S, Nexo E Increase in circulating holotranscobalamin after oral administration of cyanocobalamin or hydroxocobalamin in healthy adults with low and normal cobalamin status.. *Eur J Nutr*. (2018 Dec)

40. Greibe E, Mahalle N, Bhide V, Fedosov S, Heegaard CW, Naik S, Nexo E Effect of 8-week oral supplementation with 3-µg cyano-B12 or hydroxo-B12 in a vitamin B12-deficient population.. *Eur J Nutr*. (2019 Feb)

41. Juzeniene A, Nizauskaite Z Photodegradation of cobalamins in aqueous solutions and in human blood. *J Photochem Photobiol B*. (2013 May 5)

42. Zeisel SH, da Costa KA Choline: an essential nutrient for public health. *Nutr Rev*. (2009 Nov)

43. Gallo M, Gámiz F Choline: An Essential Nutrient for Human Health.. *Nutrients*. (2023 Jun 27)

44. Derbyshire E Could we be overlooking a potential choline crisis in the United Kingdom?. *BMJ Nutr Prev Health*. (2019)

45. Caudill MA, Strupp BJ, Muscalu L, Nevins JEH, Canfield RL Maternal choline supplementation during the third trimester of pregnancy improves infant information processing speed: a randomized, double-blind, controlled feeding study.. *FASEB J*. (2018 Apr)

46. Taylor C Wallace, Jan Krzysztof Blusztajn, Marie A Caudill, Kevin C Klatt, Elana Natker, Steven H Zeisel, Kathleen M Zelman Choline: The Underconsumed and Underappreciated Essential Nutrient. *Nutr Today*. (Nov-Dec 2018)

47. Wiedeman AM, Barr SI, Green TJ, Xu Z, Innis SM, Kitts DD Dietary Choline Intake: Current State of Knowledge Across the Life Cycle.. *Nutrients*. (2018 Oct 16)

48. Wallace TC, Fulgoni VL 3rd Assessment of Total Choline Intakes in the United States.. *J Am Coll Nutr*. (2016)

49. Wallace TC, Fulgoni VL Usual Choline Intakes Are Associated with Egg and Protein Food Consumption in the United States.. *Nutrients*. (2017 Aug 5)

50. Graham M, Clark C, Scherer A, Ratner M, Keen C An Analysis of the Nutritional Adequacy of Mass-Marketed Vegan Recipes.. *Cureus*. (2023 Apr)

51. Hess JM Modeling Dairy-Free Vegetarian and Vegan USDA Food Patterns for Nonpregnant, Nonlactating Adults.. *J Nutr*. (2022 Sep 6)

52. Tu R, Xia J Stroke and Vascular Cognitive Impairment: The Role of Intestinal Microbiota Metabolite TMAO.. *CNS Neurol Disord Drug Targets*. (2024)

53. Liu L, Kaur GI, Kumar A, Kanwal A, Singh SP The Role of Gut Microbiota and Associated Compounds in Cardiovascular Health and its Therapeutic Implications.. *Cardiovasc Hematol Agents Med Chem*. (2024 Jan 24)

54. Kong H, Cen J, Yang X, Xu Z, Liang J, Xiong Q, Zhu J Research Progress in the Relationship Between Trimethylamine Oxide and Coronary Heart Disease.. *Altern Ther Health Med*. (2024 Mar 1)

55. Christopher Papandreou, Margret Moré, Aouatef Bellamine Trimethylamine N-Oxide in Relation to Cardiometabolic Health-Cause or Effect?. *Nutrients*. (2020 May 7)

56. Giuseppina Costabile, Claudia Vetrani, Lutgarda Bozzetto, Rosalba Giacco, Letizia Bresciani, Daniele Del Rio, Marilena Vitale, Giuseppe Della Pepa, Furio Brighenti, Gabriele Riccardi, Angela A Rivellese, Giovanni Annuzzi Plasma TMAO increase after healthy diets: results from 2 randomized controlled trials with dietary fish, polyphenols, and whole-grain cereals. *Am J Clin Nutr*. (2021 Jun 5)

57. Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes and its Panel on Folate,

Other B Vitamins, and Choline Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B 6, Folate, Vitamin B 12, Pantothenic Acid, Biotin, and Choline.

58. Choline: Fact Sheet for Health Professionals; USA: National Institutes of Health Office of Dietary Supplements; last updated 2 June 2022; cited April 2024.

59. Lemos BS, Medina-Vera I, Malysheva OV, Caudill MA, Fernandez ML Effects of Egg Consumption and Choline Supplementation on Plasma Choline and Trimethylamine-N-Oxide in a Young Population. *J Am Coll Nutr*. (2018 May 15)

60. Zhu C, Sawrey-Kubicek L, Bardagjy AS, Houts H, Tang X, Sacchi R, Randolph JM, Steinberg FM, Zivkovic AM Whole egg consumption increases plasma choline and betaine without affecting TMAO levels or gut microbiome in overweight postmenopausal women.. *Nutr Res*. (2020 Jun)

61. Missimer A, Fernandez ML, DiMarco DM, Norris GH, Blesso CN, Murillo AG, Vergara-Jimenez M, Lemos BS, Medina-Vera I, Malysheva OV, Caudill MA Compared to an Oatmeal Breakfast, Two Eggs/Day Increased Plasma Carotenoids and Choline without Increasing Trimethyl Amine N-Oxide Concentrations. *J Am Coll Nutr*. (2018 Feb)

62. DiMarco DM, Missimer A, Murillo AG, Lemos BS, Malysheva OV, Caudill MA, Blesso CN, Fernandez ML Intake of up to 3 Eggs/Day Increases HDL Cholesterol and Plasma Choline While Plasma Trimethylamine-N-oxide is Unchanged in a Healthy Population. *Lipids*. (2017 Mar)

63. Thomas MS, DiBella M, Blesso CN, Malysheva O, Caudill M, Sholola M, Cooperstone JL, Fernandez ML Comparison between Egg Intake versus Choline Supplementation on Gut Microbiota and Plasma Carotenoids in Subjects with Metabolic Syndrome.. *Nutrients*. (2022 Mar 11)

64. Zuo H, Svingen GFT, Tell GS, Ueland PM, Vollset SE, Pedersen ER, Ulvik A, Meyer K, Nordrehaug JE, Nilsen DWT, Bønaa KH, Nygård O Plasma Concentrations and Dietary Intakes of Choline and Betaine in Association With Atrial Fibrillation Risk: Results From 3 Prospective Cohorts With Different Health Profiles.. *J Am Heart Assoc*. (2018 Apr 12)

65. Hosseini-Esfahani F, Koochakpoor G, Golzarand M, Mirmiran P, Azizi F Dietary Intakes of Choline and Betaine and Incidence of Type 2 Diabetes: Tehran Lipid and Glucose Study.. *Metab Syndr Relat Disord*. (2023 Dec)

66. Clara E Cho, Niklas D J Aardema, Madison L Bunnell, Deanna P Larson, Sheryl S Aguilar, Janet R Bergeson, Olga V Malysheva, Marie A Caudill, Michael Lefevre Effect of Choline Forms and Gut Microbiota Composition on Trimethylamine- N-Oxide Response in Healthy Men. *Nutrients*. (2020 Jul 25)

67. Wilcox J, Skye SM, Graham B, Zabell A, Li XS, Li L, Shelkay S, Fu X, Neale S, O'Laughlin C, Peterson K, Hazen SL, Tang WHW Dietary Choline Supplements, but Not Eggs, Raise Fasting TMAO Levels in Participants with Normal Renal Function: A Randomized Clinical Trial.. *Am J Med*. (2021 Sep)

68. Katrin A Böckmann, Axel R Franz, Michaela Minarski, Anna Shunova, Christian A Maiwald, Julian Schwarz, Maximilian Gross, Christian F Poets, Wolfgang Bernhard Differential metabolism of choline supplements in adult volunteers. *Eur J Nutr*. (2021 Jul 21)

69. Kansakar U, Trimarco V, Mone P, Varzideh F, Lombardi A, Santulli G Choline supplements: An update.. *Front Endocrinol (Lausanne)*. (2023)

70. van der Veen JN, Kennelly JP, Wan S, Vance JE, Vance DE, Jacobs RL The critical role of phosphatidylcholine and phosphatidylethanolamine metabolism in health and disease.. *Biochim Biophys Acta Biomembr*. (2017 Sep)

71. Dietary Reference Intakes.

72. Fabian Rohner, Michael Zimmermann, Pieter Jooste, Chandrakant Pandav, Kathleen Caldwell, Ramkripa Raghavan, Daniel J Raiten Biomarkers of nutrition for development--iodine review. *J Nutr*. (2014 Aug)

73. Michael B Zimmermann, Maria Andersson Assessment of iodine nutrition in populations: past, present, and future. *Nutr Rev*. (2012 Oct)

74. Eveleigh ER, Coneyworth L, Welham SJM Systematic review and meta-analysis of iodine nutrition in modern vegan and vegetarian diets.. *Br J Nutr*. (2023 Nov 14)

75. Peter P A Smyth Iodine, Seaweed, and the Thyroid. *Eur Thyroid J*. (2021 Apr)

76. Farebrother J, Zimmermann MB, Andersson M Excess iodine intake: sources, assessment, and effects on thyroid function.. *Ann N Y Acad Sci*. (2019 Jun)

77. The World Health Organization Assessment of iodine deficiency disorders and monitoring their elimination: a guide for programme managers, 3rd ed.

78. Combet E, Ma ZF, Cousins F, Thompson B, Lean ME Low-level seaweed supplementation improves iodine status in iodine-insufficient women.. *Br J Nutr*. (2014 Sep 14)

79. Aquaron R, Delange F, Marchal P, Lognoné V, Ninane L Bioavailability of seaweed iodine in human beings.. *Cell Mol Biol (Noisy-le-grand)*. (2002 Jul)

80. Clifford J Rosen, John S Adams, Daniel D Bikle, Dennis M Black, Marie B Demay, JoAnn E Manson, M Hassan Murad, Christopher S Kovacs The nonskeletal effects of vitamin D: an Endocrine Society scientific statement. *Endocr Rev*. (2012 Jun)

81. Ahmed M, Praneet Ng A, L'Abbe MR Nutrient intakes of Canadian adults: results from the Canadian Community Health Survey (CCHS)-2015 Public Use Microdata File.. *Am J Clin Nutr*. (2021 Sep 1)

82. Cowan AE, Jun S, Tooze JA, Eicher-Miller HA, Dodd KW, Gahche JJ, Guenther PM, Dwyer JT, Potischman N, Bhadra A, Bailey RL Total Usual Micronutrient Intakes Compared to the Dietary Reference Intakes among U.S. Adults by Food Security Status..

Nutrients. (2019 Dec 22)

83. Pedroza-Tobías A, Hernández-Barrera L, López-Olmedo N, García-Guerra A, Rodríguez-Ramírez S, Ramírez-Silva I, Villalpando S, Carriquiry A, Rivera JA Usual Vitamin Intakes by Mexican Populations.. *J Nutr*. (2016 Sep)
84. Cashman KD Global differences in vitamin D status and dietary intake: a review of the data.. *Endocr Connect*. (2022 Jan 11)
85. van Schoor N, Lips P Global Overview of Vitamin D Status.. *Endocrinol Metab Clin North Am*. (2017 Dec)
86. Better OS, Shabtai M, Kedar S, Melamud A, Berenheim J, Chaimovitz C Increased incidence of nephrolithiasis (N) in lifeguards (LG) in Israel.. *Adv Exp Med Biol*. (1980)
87. Zittermann A, Trummer C, Theiler-Schwetz V, Pilz S Long-term supplementation with 3200 to 4000 IU of vitamin D daily and adverse events: a systematic review and meta-analysis of randomized controlled trials.. *Eur J Nutr*. (2023-Jun)
88. Hathcock JN, Shao A, Vieth R, Heaney R Risk assessment for vitamin D. *Am J Clin Nutr*. (2007 Jan)
89. Bischoff-Ferrari HA, Dawson-Hughes B, Orav EJ, Staehelin HB, Meyer OW, Theiler R, Dick W, Willett WC, Egli A Monthly High-Dose Vitamin D Treatment for the Prevention of Functional Decline: A Randomized Clinical Trial. *JAMA Intern Med*. (2016 Feb)
90. Lawrence J Appel, Erin D Michos, Christine M Mitchell, Amanda L Blackford, Alice L Sternberg, Edgar R Miller 3rd, Stephen P Juraschek, Jennifer A Schrack, Sarah L Szanton, Jeanne Charleston, Melissa Minotti, Sheriza N Baksh, Robert H Christenson, Josef Coresh, Lea T Drye, Jack M Guralnik, Rita R Kalyani, Timothy B Plante, David M Shade, David L Roth, James Tonascia, STURDY Collaborative Research Group The Effects of Four Doses of Vitamin D Supplements on Falls in Older Adults : A Response-Adaptive, Randomized Clinical Trial. *Ann Intern Med*. (2021 Feb)
91. Wanigatunga AA, Sternberg AL, Blackford AL, Cai Y, Mitchell CM, Roth DL, Miller ER, Szanton SL, Juraschek SP, Michos ED, Schrack JA, Appel LJ, The effects of vitamin D supplementation on types of falls.. *J Am Geriatr Soc*. (2021-Oct)
92. Schlingmann KP, Kaufmann M, Weber S, Irwin A, Goos C, John U, Misselwitz J, Klaus G, Kuwertz-Bröking E, Fehrenbach H, Wingen AM, Güran T, Hoenderop JG, Bindels RJ, Prosser DE, Jones G, Konrad M Mutations in CYP24A1 and idiopathic infantile hypercalcemia. *N Engl J Med*. (2011 Aug 4)
93. Vitamin D Fact sheet for health professionals. MedlinePlus. National Institutes of Health (NIH) Office of Dietary Supplements (ODS). Updated 2022 Aug 12; cited 2023 May 22.
94. McDuffie JR, Calis KA, Booth SL, Uwaifo GI, Yanovski JA Effects of orlistat on fat-soluble vitamins in obese adolescents.. *Pharmacotherapy*. (2002-Jul)
95. Kim Robien, Sarah J Oppeneer, Julia A Kelly, Jill M Hamilton-Reeves Drug-vitamin D interactions: a systematic review of the literature. *Nutr Clin Pract*. (2013 Apr)
96. Skversky AL, Kumar J, Abramowitz MK, Kaskel FJ, Melamed ML Association of glucocorticoid use and low 25-hydroxyvitamin D levels: results from the National Health and Nutrition Examination Survey (NHANES): 2001-2006.. *J Clin Endocrinol Metab*. (2011-Dec)
97. Crowe M, Wollner L, Griffiths RA Hypercalcaemia following vitamin D and thiazide therapy in the elderly.. *Practitioner*. (1984-Mar)
98. P J Drinka, W E Nolten Hazards of treating osteoporosis and hypertension concurrently with calcium, vitamin D, and distal diuretics. *J Am Geriatr Soc*. (1984 May)
99. Pludowski P, Grant WB, Karras SN, Zittermann A, Pilz S Vitamin D Supplementation: A Review of the Evidence Arguing for a Daily Dose of 2000 International Units (50 µg) of Vitamin D for Adults in the General Population.. *Nutrients*. (2024 Jan 29)
100. Mulligan GB, Licata A Taking vitamin D with the largest meal improves absorption and results in higher serum levels of 25-hydroxyvitamin D.. *J Bone Miner Res*. (2010-Apr)
101. Dawson-Hughes B, Harris SS, Palermo NJ, Ceglia L, Rasmussen H Meal conditions affect the absorption of supplemental vitamin D3 but not the plasma 25-hydroxyvitamin D response to supplementation. *J Bone Miner Res*. (2013 Aug)
102. 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)
103. Anatoly V Skalny, Michael Aschner, Alexey A Tinkov Zinc. *Adv Food Nutr Res*. (2021)
104. Stiles LI, Ferrao K, Mehta KJ Role of zinc in health and disease.. *Clin Exp Med*. (2024 Feb 17)
105. Fredlund K, Isaksson M, Rossander-Hulthén L, Almgren A, Sandberg AS Absorption of zinc and retention of calcium: dose-dependent inhibition by phytate.. *J Trace Elem Med Biol*. (2006)
106. Foster M, Chu A, Petocz P, Samman S Effect of vegetarian diets on zinc status: a systematic review and meta-analysis of studies in humans.. *J Sci Food Agric*. (2013 Aug 15)
107. Craig WJ, Mangels AR, Fresán U, Marsh K, Miles FL, Saunders AV, Haddad EH, Heskey CE, Johnston P, Larson-Meyer E, Orlich M The Safe and Effective Use of Plant-Based Diets with Guidelines for Health Professionals.. *Nutrients*. (2021-Nov-19)
108. Hunt JR Bioavailability of iron, zinc, and other trace minerals from vegetarian diets. *Am J Clin Nutr*. (2003 Sep)
109. Foster M, Samman S Vegetarian diets across the lifecycle: impact on zinc intake and status.. *Adv Food Nutr Res*. (2015)
110. Hunt JR, Beiseigel JM, Johnson LK Adaptation in human zinc absorption as influenced by dietary zinc and bioavailability.. *Am J Clin Nutr*. (2008 May)
111. Gibson RS, Raboy V, King JC Implications of phytate in plant-based foods for iron and zinc bioavailability, setting dietary

requirements, and formulating programs and policies.. *Nutr Rev*. (2018-Nov-01)

112. Gibson RS, Perlas L, Hotz C Improving the bioavailability of nutrients in plant foods at the household level.. *Proc Nutr Soc*. (2006 May)

113. Weston Petroski, Deanna M Minich Is There Such a Thing as "Anti-Nutrients"? A Narrative Review of Perceived Problematic Plant Compounds. *Nutrients*. (2020 Sep 24)

114. https://www.ncbi.nlm.nih.gov/books/NBK222317/.

115. King JC Zinc: an essential but elusive nutrient.. *Am J Clin Nutr*. (2011 Aug)

116. Institute of Medicine (US) Panel on Micronutrients Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc.

117. Duncan A, Yacoubian C, Watson N, Morrison I The risk of copper deficiency in patients prescribed zinc supplements. *J Clin Pathol*. (2015 Sep)

118. Shankar AH, Prasad AS Zinc and immune function: the biological basis of altered resistance to infection.. *Am J Clin Nutr*. (1998-Aug)

119. Lomaestro BM, Bailie GR Absorption interactions with fluoroquinolones. 1995 update.. *Drug Saf*. (1995-May)

120. Penttilä O, Hurme H, Neuvonen PJ Effect of zinc sulphate on the absorption of tetracycline and doxycycline in man.. *Eur J Clin Pharmacol*. (1975-Dec-19)

121. Blondeau JM Expanded activity and utility of the new fluoroquinolones: a review.. *Clin Ther*. (1999-Jan)

122. Beauduy CE & Winston LG Basic & clinical pharmacology, chapter 46: sulfonamides, trimethoprim, & quinolones.

123. Wester PO Urinary zinc excretion during treatment with different diuretics.. *Acta Med Scand*. (1980)

124. Wegmüller R, Tay F, Zeder C, Brnic M, Hurrell RF Zinc absorption by young adults from supplemental zinc citrate is comparable with that from zinc gluconate and higher than from zinc oxide. *J Nutr*. (2014 Feb)

125. Piacenza F, Giacconi R, Costarelli L, Malavolta M Preliminary Comparison of Fractional Absorption of Zinc Sulphate, Zinc Gluconate, and Zinc Aspartate after Oral Supple-Mentation in Healthy Human Volunteers.. *Nutrients*. (2023 Apr 13)

126. Siepmann M, Spank S, Kluge A, Schappach A, Kirch W The pharmacokinetics of zinc from zinc gluconate: a comparison with zinc oxide in healthy men.. *Int J Clin Pharmacol Ther*. (2005 Dec)

127. Candow DG, Forbes SC, Ostojic SM, Prokopidis K, Stock MS, Harmon KK, Faulkner P "Heads Up" for Creatine Supplementation and its Potential Applications for Brain Health and Function.. *Sports Med*. (2023-Jun-27)

128. Fons C, Campistol J Creatine Defects and Central Nervous System.. *Semin Pediatr Neurol*. (2016-Nov)

129. Ostojic SM Low Tissue Creatine: A Therapeutic Target in Clinical Nutrition.. *Nutrients*. (2022-Mar-15)

130. Mojtaba Kaviani, Keely Shaw, Philip D Chilibeck Benefits of Creatine Supplementation for Vegetarians Compared to Omnivorous Athletes: A Systematic Review. *Int J Environ Res Public Health*. (2020 Apr 27)

131. Marina Yazigi Solis, Guilherme Giannini Artioli, Maria Concepción García Otaduy, Claudia da Costa Leite, Walquiria Arruda, Raquel Ramos Veiga, Bruno Gualano Effect of age, diet, and tissue type on PCr response to creatine supplementation. *J Appl Physiol (1985)*. (2017 Aug 1)

132. Yazigi Solis M, de Salles Painelli V, Giannini Artioli G, Roschel H, Concepción Otaduy M, Gualano B Brain creatine depletion in vegetarians? A cross-sectional ^{1}H-magnetic resonance spectroscopy (^{1}H-MRS) study.. *Br J Nutr*. (2014-Apr-14)

133. Domenichiello AF, Kitson AP, Bazinet RP Is docosahexaenoic acid synthesis from α-linolenic acid sufficient to supply the adult brain?. *Prog Lipid Res*. (2015 Jul)

134. Ellouze I, Sheffler J, Nagpal R, Arjmandi B Dietary Patterns and Alzheimer's Disease: An Updated Review Linking Nutrition to Neuroscience.. *Nutrients*. (2023 Jul 19)

135. Glaister M, Rhodes L Short-Term Creatine Supplementation and Repeated Sprint Ability-A Systematic Review and Meta-Analysis.. *Int J Sport Nutr Exerc Metab*. (2022 Nov 1)

136. Mielgo-Ayuso J, Calleja-Gonzalez J, Marqués-Jiménez D, Caballero-García A, Córdova A, Fernández-Lázaro D Effects of Creatine Supplementation on Athletic Performance in Soccer Players: A Systematic Review and Meta-Analysis.. *Nutrients*. (2019-Mar-31)

137. Lanhers C, Pereira B, Naughton G, Trousselard M, Lesage FX, Dutheil F Creatine Supplementation and Upper Limb Strength Performance: A Systematic Review and Meta-Analysis.. *Sports Med*. (2017-Jan)

138. Charlotte Lanhers, Bruno Pereira, Geraldine Naughton, Marion Trousselard, François-Xavier Lesage, Frédéric Dutheil Creatine Supplementation and Lower Limb Strength Performance: A Systematic Review and Meta-Analyses. *Sports Med*. (2015 Sep)

139. Burke R, Piñero A, Coleman M, Mohan A, Sapuppo M, Augustin F, Aragon AA, Candow DG, Forbes SC, Swinton P, Schoenfeld BJ The Effects of Creatine Supplementation Combined with Resistance Training on Regional Measures of Muscle Hypertrophy: A Systematic Review with Meta-Analysis.. *Nutrients*. (2023 Apr 28)

140. Prokopidis K, Giannos P, Triantafyllidis KK, Kechagias KS, Forbes SC, Candow DG Effects of creatine supplementation on memory in healthy individuals: a systematic review and meta-analysis of randomized controlled trials.. *Nutr Rev*. (2023-Mar-10)

141. Prokopidis K, Giannos P, Triantafyllidis KK, Kechagias KS, Forbes SC, Candow DG Author's reply: Letter to the Editor: Double counting due to inadequate statistics leads to false-positive findings in "Effects of creatine supplementation on memory in

healthy individuals: a systematic review and meta-analysis of randomized controlled trials"..*Nutr Rev*. (2023-Oct-10)

142. Sandkühler JF, Kersting X, Faust A, Königs EK, Altman G, Ettinger U, Lux S, Philipsen A, Müller H, Brauner J The effects of creatine supplementation on cognitive performance-a randomised controlled study.. *BMC Med*. (2023-Nov-15)

143. Benton D, Donohoe R The influence of creatine supplementation on the cognitive functioning of vegetarians and omnivores. *Br J Nutr*. (2011 Apr)

144. Rae C, Digney AL, McEwan SR, Bates TC Oral creatine monohydrate supplementation improves brain performance: a double-blind, placebo-controlled, cross-over trial. *Proc Biol Sci*. (2003 Oct 22)

145. 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)

146. Ostojic SM, Ahmetovic Z Gastrointestinal distress after creatine supplementation in athletes: are side effects dose dependent?. *Res Sports Med*. (2008)

147. Antonio J, Candow D, Forbes S, et al. Common questions and misconceptions about creatine supplementation: what does the scientific evidence really show?. *Journal of the International Society of Sports Nutrition*. (2021 Feb)

148. Larissa Gorayb Ferreira, Cássia De Toledo Bergamaschi, Marise Lazaretti-Castro, Ita P Heilberg Effects of creatine supplementation on body composition and renal function in rats. *Med Sci Sports Exerc*. (2005 Sep)

149. Edmunds JW, Jayapalan S, DiMarco NM, Saboorian MH, Aukema HM Creatine supplementation increases renal disease progression in Han:SPRD-cy rats.. *Am J Kidney Dis*. (2001-Jan)

150. Tarnopolsky MA, Bourgeois JM, Snow R, Keys S, Roy BD, Kwiecien JM, Turnbull J Histological assessment of intermediate- and long-term creatine monohydrate supplementation in mice and rats.. *Am J Physiol Regul Integr Comp Physiol*. (2003-Oct)

151. Poortmans JR, Francaux M Long-term oral creatine supplementation does not impair renal function in healthy athletes. *Med Sci Sports Exerc*. (1999 Aug)

152. Kreider RB, Melton C, Rasmussen CJ, Greenwood M, Lancaster S, Cantler EC, Milnor P, Almada AL Long-term creatine supplementation does not significantly affect clinical markers of health in athletes.. *Mol Cell Biochem*. (2003-Feb)

153. Domingues WJR, Ritti-Dias RM, Cucato GG, Wolosker N, Zerati AE, Puech-Leão P, Nunhes PM, Moliterno AA, Avelar A Does Creatine Supplementation Affect Renal Function in Patients with Peripheral Artery Disease? A Randomized, Double Blind, Placebo-controlled, Clinical Trial.. *Ann Vasc Surg*. (2020-Feb)

154. Gualano B, de Salles Painelli V, Roschel H, Lugaresi R, Dorea E, Artioli GG, Lima FR, da Silva ME, Cunha MR, Seguro AC, Shimizu MH, Otaduy MC, Sapienza MT, da Costa Leite C, Bonfá E, Lancha Junior AH Creatine supplementation does not impair kidney function in type 2 diabetic patients: a randomized, double-blind, placebo-controlled, clinical trial. *Eur J Appl Physiol*. (2011 May)

155. Ziegenfuss T, Lowery L, Lemon P Acute fluid volume changes in men during three days of creatine supplementation. *Journal of Exercise Physiology Online*. (1998 Oct)

156. Dalbo VJ, Roberts MD, Stout JR, Kerksick CM Putting to rest the myth of creatine supplementation leading to muscle cramps and dehydration.. *Br J Sports Med*. (2008-Jul)

157. Rawson ES, Clarkson PM, Tarnopolsky MA Perspectives on Exertional Rhabdomyolysis.. *Sports Med*. (2017-Mar)

158. de Souza E Silva A, Pertille A, Reis Barbosa CG, Aparecida de Oliveira Silva J, de Jesus DV, Ribeiro AGSV, Baganha RJ, de Oliveira JJ Effects of Creatine Supplementation on Renal Function: A Systematic Review and Meta-Analysis.. *J Ren Nutr*. (2019-Nov)

159. Chang CT, Wu CH, Yang CW, Huang JY, Wu MS Creatine monohydrate treatment alleviates muscle cramps associated with haemodialysis.. *Nephrol Dial Transplant*. (2002-Nov)

160. Kutz MR, Gunter MJ Creatine monohydrate supplementation on body weight and percent body fat. *J Strength Cond Res*. (2003 Nov)

161. Heymsfield SB, Arteaga C, McManus C, Smith J, Moffitt S Measurement of muscle mass in humans: validity of the 24-hour urinary creatinine method.. *Am J Clin Nutr*. (1983-Mar)

162. Demant TW, Rhodes EC Effects of creatine supplementation on exercise performance.. *Sports Med*. (1999-Jul)

163. Damien Gras, Charlotte Lanhers, Reza Bagheri, Ukadike Chris Ugbolue, Emmanuel Coudeyre, Bruno Pereira, Marek Zak, Jean-Baptiste Bouillon-Minois, Frédéric Dutheil Creatine supplementation and VO 2 max: a systematic review and meta-analysis. *Crit Rev Food Sci Nutr*. (2021 Dec 3)

164. P D Balsom, S D Harridge, K Söderlund, B Sjödin, B Ekblom Creatine supplementation per se does not enhance endurance exercise performance. *Acta Physiol Scand*. (1993 Dec)

165. 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)

166. 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)

167. 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)

168. 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)

169. 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)

170. Eijnde BO, Hespel P Short-term creatine supplementation does not alter the hormonal response to resistance training. *Med Sci Sports Exerc*. (2001 Mar)

171. 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)

172. Tyka AK, Chwastowski M, Cison T, Palka T, Tyka A, Szygula Z, Pilch W, Strzala M, Cepero M Effect of creatine malate supplementation on physical performance, body composition and selected hormone levels in spinters and long-distance runners. *Acta Physiol Hung*. (2015 Mar)

173. Sheikholeslami D et al The effects of creatine supplementation on performance and hormonal response in amateur swimmers. *Science & Sport*. (2011 Nov)

174. Arazi H et al. Effects of short term creatine supplementation and resistance exercises on resting hormonal and cardiovascular responses. *Science & Sport*. (2015 Apr)

175. Faraji H et al. The effects of creatine supplementation on sprint running performance and selected hormonal responses. *S Afr J Res Sport Ph*. (2010)

176. Rahimi R et al. Creatine supplementation alters the hormonal response to resistance exercise. *Kinesiology*. (2011)

177. Volek JS, Rawson ES Scientific basis and practical aspects of creatine supplementation for athletes.. *Nutrition*. (2004)

178. Antonio J, Candow DG, Forbes SC, Gualano B, Jagim AR, Kreider RB, Rawson ES, Smith-Ryan AE, VanDusseldorp TA, Willoughby DS, Ziegenfuss TN Common questions and misconceptions about creatine supplementation: what does the scientific evidence really show?. *J Int Soc Sports Nutr*. (2021-Feb-08)

179. Sobolewsky E, Thompson B, Smith A, Ryan E The Physiological Effects of Creatine Supplementation on Hydration: A Review. *Am J Lifestyle Med*. (2011 May)

180. Institute of Medicine, Food and Nutrition Board Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino acids.

181. Baker EJ, Miles EA, Burdge GC, Yaqoob P, Calder PC Metabolism and functional effects of plant-derived omega-3 fatty acids in humans. *Prog Lipid Res*. (2016 Oct)

182. Davis BC, Kris-Etherton PM Achieving optimal essential fatty acid status in vegetarians: current knowledge and practical implications.. *Am J Clin Nutr*. (2003 Sep)

183. Qian F, Ardisson Korat AV, Imamura F, Marklund M, Tintle N, Virtanen JK, Zhou X, Bassett JK, Lai H, Hirakawa Y, Chien KL, Wood AC, Lankinen M, Murphy RA, Samieri C, Pertiwi K, de Mello VD, Guan W, Forouhi NG, Wareham N, Hu ICFB, Riserus U, Lind L, Harris WS, Shadyab AH, Robinson JG, Steffen LM, Hodge A, Giles GG, Ninomiya T, Uusitupa M, Tuomilehto J, Lindström J, Laakso M, Siscovick DS, Helmer C, Geleijnse JM, Wu JHY, Fretts A, Lemaitre RN, Micha R, Mozaffarian D, Sun Q, n-3 Fatty Acid Biomarkers and Incident Type 2 Diabetes: An Individual Participant-Level Pooling Project of 20 Prospective Cohort Studies.. *Diabetes Care*. (2021-May)

184. Ong KL, Marklund M, Huang L, Rye KA, Hui N, Pan XF, Rebholz CM, Kim H, Steffen LM, van Westing AC, Geleijnse JM, Hoogeveen EK, Chen YY, Chien KL, Fretts AM, Lemaitre RN, Imamura F, Forouhi NG, Wareham NJ, Birukov A, Jäger S, Kuxhaus O, Schulze MB, de Mello VD, Tuomilehto J, Uusitupa M, Lindström J, Tintle N, Harris WS, Yamasaki K, Hirakawa Y, Ninomiya T, Tanaka T, Ferrucci L, Bandinelli S, Virtanen JK, Voutilainen A, Jayasena T, Thalamuthu A, Poljak A, Bustamante S, Sachdev PS, Senn MK, Rich SS, Tsai MY, Wood AC, Laakso M, Lankinen M, Yang X, Sun L, Li H, Lin X, Nowak C, Ärnlöv J, Risérus U, Lind L, Le Goff M, Samieri C, Helmer C, Qian F, Micha R, Tin A, Köttgen A, de Boer IH, Siscovick DS, Mozaffarian D, Wu JH Association of omega 3 polyunsaturated fatty acids with incident chronic kidney disease: pooled analysis of 19 cohorts.. *BMJ*. (2023-Jan-18)

185. Kim Y, Kim J Intake or Blood Levels of n-3 Polyunsaturated Fatty Acids and Risk of Colorectal Cancer: A Systematic Review and Meta-analysis of Prospective Studies.. *Cancer Epidemiol Biomarkers Prev*. (2020 Feb)

186. Sven J van der Lee, Charlotte E Teunissen, René Pool, Martin J Shipley, Alexander Teumer, Vincent Chouraki, Debora Melo van Lent, Juho Tynkkynen, Krista Fischer, Jussi Hernesniemi, Toomas Haller, Archana Singh-Manoux, Aswin Verhoeven, Gonneke Willemsen, Francisca A de Leeuw, Holger Wagner, Jenny van Dongen, Johannes Hertel, Kathrin Budde, Ko Willems van Dijk, Leonie Weinhold, M Arfan Ikram, Maik Pietzner, Markus Perola, Michael Wagner, Nele Friedrich, P Eline Slagboom, Philip Scheltens, Qiong Yang, Robert E Gertzen, Sarah Egert, Shuo Li, Thomas Hankemeier, Catharina E M van Beijsterveldt, Ramachandran S Vasan, Wolfgang Maier, Carel F W Peeters, Hans Jörgen Grabe, Alfredo Ramirez, Sudha Seshadri, Andres Metspalu, Mika Kivimäki, Veikko Salomaa, Ayşe Demirkan, Dorret I Boomsma, Wiesje M van der Flier, Najaf Amin, Cornelia M van Duijn Circulating metabolites and general cognitive ability and dementia: Evidence from 11 cohort studies. *Alzheimers Dement*. (2018 Jun)

187. He Y, Huang SY, Wang HF, Zhang W, Deng YT, Zhang YR, Dong Q, Feng JF, Cheng W, Yu JT Circulating polyunsaturated fatty acids, fish oil supplementation, and risk of incident dementia: a prospective cohort study of 440,750 participants.. *Geroscience*. (2023 Jun)

188. Wei BZ, Li L, Dong CW, Tan CC, Alzheimer's Disease Neuroimaging Initiative, Xu W The Relationship of Omega-3 Fatty Acids with Dementia and Cognitive Decline: Evidence from Prospective Cohort Studies of Supplementation, Dietary Intake, and Blood

Markers.. *Am J Clin Nutr*. (2023 Jun)

189. William S Harris, Nathan L Tintle, Fumiaki Imamura, Frank Qian, Andres V Ardisson Korat, Matti Marklund, Luc Djoussé, Julie K Bassett, Pierre-Hugues Carmichael, Yun-Yu Chen, Yoichiro Hirakawa, Leanne K Küpers, Federica Laguzzi, Maria Lankinen, Rachel A Murphy, Cécilia Samieri, Mackenzie K Senn, Peilin Shi, Jyrki K Virtanen, Ingeborg A Brouwer, Kuo-Liong Chien, Gudny Eiriksdottir, Nita G Forouhi, Johanna M Geleijnse, Graham G Giles, Vilmundur Gudnason, Catherine Helmer, Allison Hodge, Rebecca Jackson, Kay-Tee Khaw, Markku Laakso, Heidi Lai, Danielle Laurin, Karin Leander, Joan Lindsay, Renata Micha, Jaako Mursu, Toshiharu Ninomiya, Wendy Post, Bruce M Psaty, Ulf Risérus, Jennifer G Robinson, Aladdin H Shadyab, Linda Snetselaar, Aleix Sala-Vila, Yangbo Sun, Lyn M Steffen, Michael Y Tsai, Nicholas J Wareham, Alexis C Wood, Jason H Y Wu, Frank Hu, Qi Sun, David S Siscovick, Rozenn N Lemaitre, Dariush Mozaffarian, Fatty Acids and Outcomes Research Consortium (FORCE) Blood n-3 fatty acid levels and total and cause-specific mortality from 17 prospective studies. *Nat Commun*. (2021 Apr 22)

190. Bonny Burns-Whitmore, Erik Froyen, Celine Heskey, Temetra Parker, Gregorio San Pablo Alpha-Linolenic and Linoleic Fatty Acids in the Vegan Diet: Do They Require Dietary Reference Intake/Adequate Intake Special Consideration?. *Nutrients*. (2019 Oct 4)

191. Wang Y, Liu B, Han H, Hu Y, Zhu L, Rimm EB, Hu FB, Sun Q Associations between plant-based dietary patterns and risks of type 2 diabetes, cardiovascular disease, cancer, and mortality - a systematic review and meta-analysis.. *Nutr J*. (2023-Oct-04)

192. Harris WS Achieving optimal n-3 fatty acid status: the vegetarian's challenge... or not.. *Am J Clin Nutr*. (2014-Jul)

193. Stephen J Nicholls, A Michael Lincoff, Michelle Garcia, Dianna Bash, Christie M Ballantyne, Philip J Barter, Michael H Davidson, John J P Kastelein, Wolfgang Koenig, Darren K McGuire, Dariush Mozaffarian, Paul M Ridker, Kausik K Ray, Brian G Katona, Anders Himmelmann, Larrye E Loss, Martin Rensfeldt, Torbjörn Lundström, Rahul Agrawal, Venu Menon, Kathy Wolski, Steven E Nissen Effect of High-Dose Omega-3 Fatty Acids vs Corn Oil on Major Adverse Cardiovascular Events in Patients at High Cardiovascular Risk: The STRENGTH Randomized Clinical Trial. *JAMA*. (2020 Dec 8)

194. Wang C, Chung M, Lichtenstein A, Balk E, Kupelnick B, DeVine D, Lawrence A, Lau J Effects of omega-3 fatty acids on cardiovascular disease.. *Evid Rep Technol Assess (Summ)*. (2004-Mar)

195. Cleland LG, James MJ, Proudman SM Fish oil: what the prescriber needs to know.. *Arthritis Res Ther*. (2006)

196. Buckley MS, Goff AD, Knapp WE Fish oil interaction with warfarin.. *Ann Pharmacother*. (2004-Jan)

197. Elizabeth M McClaskey, Elizabeth Landrum Michalets Subdural hematoma after a fall in an elderly patient taking high-dose omega-3 fatty acids with warfarin and aspirin: case report and review of the literature. *Pharmacotherapy*. (2007 Jan)

198. Kristof Vanschoonbeek, Marion A H Feijge, Martine Paquay, Jan Rosing, Wim Saris, Cornelis Kluft, Peter L A Giesen, Moniek P M de Maat, Johan W M Heemskerk Variable hypocoagulant effect of fish oil intake in humans: modulation of fibrinogen level and thrombin generation. *Arterioscler Thromb Vasc Biol*. (2004 Sep)

199. Burke BE, Neuenschwander R, Olson RD Randomized, double-blind, placebo-controlled trial of coenzyme Q10 in isolated systolic hypertension. *South Med J*. (2001 Nov)

200. John Alfred Carr Role of Fish Oil in Post-Cardiotomy Bleeding: A Summary of the Basic Science and Clinical Trials. *Ann Thorac Surg*. (2018 May)

201. Begtrup KM, Krag AE, Hvas AM No impact of fish oil supplements on bleeding risk: a systematic review. *Dan Med J*. (2017 May)

202. 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)

203. 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)

204. Bengtson Nash SM, Schlabach M, Nichols PD A nutritional-toxicological assessment of Antarctic krill oil versus fish oil dietary supplements. *Nutrients*. (2014 Aug 28)

205. 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)

206. 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)

207. Safi U Khan, Ahmad N Lone, Muhammad Shahzeb Khan, Salim S Virani, Roger S Blumenthal, Khurram Nasir, Michael Miller, Erin D Michos, Christie M Ballantyne, William E Boden, Deepak L Bhatt Effect of omega-3 fatty acids on cardiovascular outcomes: A systematic review and meta-analysis. *EClinicalMedicine*. (2021 Jul 8)

208. Bernstein AM, Ding EL, Willett WC, Rimm EB A meta-analysis shows that docosahexaenoic acid from algal oil reduces serum triglycerides and increases HDL-cholesterol and LDL-cholesterol in persons without coronary heart disease. *J Nutr*. (2012 Jan)

209. Katie E Lane, Megan Wilson, Teuta G Hellon, Ian G Davies Bioavailability and conversion of plant based sources of omega-3 fatty acids - a scoping review to update supplementation options for vegetarians and vegans. *Crit Rev Food Sci Nutr*. (2021 Feb 12)

210. Barbara Sarter, Kristine S Kelsey, Todd A Schwartz, William S Harris Blood docosahexaenoic acid and eicosapentaenoic acid in vegans: Associations with age and gender and effects of an algal-derived omega-3 fatty acid supplement. *Clin Nutr*. (2015 Apr)

211. Dempsey M, Rockwell MS, Wentz LM The influence of dietary and supplemental omega-3 fatty acids on the omega-3 index: A scoping review.. *Front Nutr*. (2023)

212. Indiveri C, Iacobazzi V, Tonazzi A, Giangregorio N, Infantino V, Convertini P, Console L, Palmieri F The mitochondrial carnitine/acylcarnitine carrier: function, structure and physiopathology.. *Mol Aspects Med*. (2011-Aug)

213. Pekala J, Patkowska-Sokoła B, Bodkowski R, Jamroz D, Nowakowski P, Lochyński S, Librowski T L-carnitine--metabolic functions and meaning in humans life. *Curr Drug Metab*. (2011 Sep)

214. Reuter SE, Evans AM Carnitine and acylcarnitines: pharmacokinetic, pharmacological and clinical aspects.. *Clin Pharmacokinet*. (2012-Sep-01)

215. Demir Djekic, Lin Shi, Harald Brolin, Frida Carlsson, Charlotte Särnqvist, Otto Savolainen, Yang Cao, Fredrik Bäckhed, Valentina Tremaroli, Rikard Landberg, Ole Frøbert Effects of a Vegetarian Diet on Cardiometabolic Risk Factors, Gut Microbiota, and Plasma Metabolome in Subjects With Ischemic Heart Disease: A Randomized, Crossover Study. *J Am Heart Assoc*. (2020 Sep 15)

216. Juncker HG, van den Akker CHP, Meerdink PL, Korosi A, Vaz FM, van Goudoever JB, van Keulen BJ The influence of a maternal vegan diet on carnitine and vitamin B2 concentrations in human milk.. *Front Nutr*. (2023)

217. Lombard KA, Olson AL, Nelson SE, Rebouche CJ Carnitine status of lactoovovegetarians and strict vegetarian adults and children. *Am J Clin Nutr*. (1989 Aug)

218. Novakova K, Kummer O, Bouitbir J, Stoffel SD, Hoerler-Koerner U, Bodmer M, Roberts P, Urwyler A, Ehrsam R, Krähenbühl S Effect of L-carnitine supplementation on the body carnitine pool, skeletal muscle energy metabolism and physical performance in male vegetarians. *Eur J Nutr*. (2016 Feb)

219. Tsung-Jen Lin, Sheau-Chung Tang, Pei-Yun Liao, Rachmad Anres Dongoran, Jen-Hung Yang, Chin-Hung Liu A comparison of L-carnitine and several cardiovascular-related biomarkers between healthy vegetarians and omnivores. *Nutrition*. (2019 Oct)

220. Blancquaert L, Baguet A, Bex T, Volkaert A, Everaert I, Delanghe J, Petrovic M, Vervaet C, De Henauw S, Constantin-Teodosiu D, Greenhaff P, Derave W Changing to a vegetarian diet reduces the body creatine pool in omnivorous women, but appears not to affect carnitine and carnosine homeostasis: a randomised trial.. *Br J Nutr*. (2018-Apr)

221. Rebouche CJ, Chenard CA Metabolic fate of dietary carnitine in human adults: identification and quantification of urinary and fecal metabolites. *J Nutr*. (1991 Apr)

222. Heidrun Karlic, Daniela Schuster, Franz Varga, Gerhard Klindert, Alexander Lapin, Alexander Haslberger, Michael Handschur Vegetarian diet affects genes of oxidative metabolism and collagen synthesis. *Ann Nutr Metab*. (2008)

223. Cesak O, Vostalova J, Vidlar A, Bastlova P, Student V Jr Carnosine and Beta-Alanine Supplementation in Human Medicine: Narrative Review and Critical Assessment.. *Nutrients*. (2023 Apr 5)

224. Derave W, Everaert I, Beeckman S, Baguet A Muscle carnosine metabolism and beta-alanine supplementation in relation to exercise and training.. *Sports Med*. (2010 Mar 1)

225. Everaert I, Mooyaart A, Baguet A, Zutinic A, Baelde H, Achten E, Taes Y, De Heer E, Derave W Vegetarianism, female gender and increasing age, but not CNDP1 genotype, are associated with reduced muscle carnosine levels in humans. *Amino Acids*. (2011 Apr)

226. Feehan J, Hariharan R, Buckenham T, Handley C, Bhatnagar A, Baba SP, de Courten B Carnosine as a potential therapeutic for the management of peripheral vascular disease.. *Nutr Metab Cardiovasc Dis*. (2022 Oct)

227. Frank Gaunitz, Alan R Hipkiss Carnosine and cancer: a perspective. *Amino Acids*. (2012 Jul)

228. Solana-Manrique C, Sanz FJ, Martínez-Carrión G, Paricio N Antioxidant and Neuroprotective Effects of Carnosine: Therapeutic Implications in Neurodegenerative Diseases.. *Antioxidants (Basel)*. (2022 Apr 26)

229. Saunders B, Elliott-Sale K, Artioli GG, Swinton PA, Dolan E, Roschel H, Sale C, Gualano B β-alanine supplementation to improve exercise capacity and performance: a systematic review and meta-analysis. *Br J Sports Med*. (2017 Apr)

230. Pohl A, Schünemann F, Bersiner K, Gehlert S The Impact of Vegan and Vegetarian Diets on Physical Performance and Molecular Signaling in Skeletal Muscle.. *Nutrients*. (2021 Oct 29)

231. Joseph J Matthews, Guilherme G Artioli, Mark D Turner, Craig Sale The Physiological Roles of Carnosine and β-Alanine in Exercising Human Skeletal Muscle. *Med Sci Sports Exerc*. (2019 Oct)

232. Sale C, Artioli GG, Gualano B, Saunders B, Hobson RM, Harris RC Carnosine: from exercise performance to health.. *Amino Acids*. (2013 Jun)

233. Rezende NS, Bestetti GC, Farias de Oliveira L, Mazzolani BC, Smaira FI, Dumas A, Swinton P, Saunders B, Dolan E Dietary β-Alanine Intake Assessed by Food Records Does Not Associate With Muscle Carnosine Content in Healthy, Active, Omnivorous Men and Women.. *Int J Sport Nutr Exerc Metab*. (2023 May 1)

234. Caruso J, Charles J, Unruh K, Giebel R, Learmonth L, Potter W Ergogenic effects of β-alanine and carnosine: proposed future research to quantify their efficacy.. *Nutrients*. (2012 Jul)

235. Gonzalez DE, McAllister MJ, Waldman HS, Ferrando AA, Joyce J, Barringer ND, Dawes JJ, Kieffer AJ, Harvey T, Kerksick CM, Stout JR, Ziegenfuss TN, Zapp A, Tartar JL, Heileson JL, VanDusseldorp TA, Kalman DS, Campbell BI, Antonio J, Kreider RB International society of sports nutrition position stand: tactical athlete nutrition.. *J Int Soc Sports Nutr*. (2022)

236. Stellingwerff T, Anwander H, Egger A, Buehler T, Kreis R, Decombaz J, Boesch C Effect of two β-alanine dosing protocols on muscle carnosine synthesis and washout. *Amino Acids*. (2012 Jun)

237. Sanne Stegen, Tine Bex, Chris Vervaet, Lander Vanhee, Eric Achten, Wim Derave β-Alanine dose for maintaining moderately elevated muscle carnosine levels. *Med Sci Sports Exerc*. (2014 Jul)

238. Geissler C, Singh M Iron, meat and health.. *Nutrients*. (2011 Mar)

239. Vanek T, Kohli A Biochemistry, Myoglobin.. *StatPearls*. (2024 Jan)

240. Lisa M Haider, Lukas Schwingshackl, Georg Hoffmann, Cem Ekmekcioglu The effect of vegetarian diets on iron status in adults: A systematic review and meta-analysis. *Crit Rev Food Sci Nutr*. (2018 May 24)

241. Saunders AV, Craig WJ, Baines SK, Posen JS Iron and vegetarian diets.. *Med J Aust*. (2013 Aug 19)

242. Seth M Armah, Alicia Carriquiry, Debra Sullivan, James D Cook, Manju B Reddy A complete diet-based algorithm for predicting nonheme iron absorption in adults. *J Nutr*. (2013 Jul)

243. Hurrell R, Egli I Iron bioavailability and dietary reference values.. *Am J Clin Nutr*. (2010 May)

244. J R Hunt, Z K Roughead Nonheme-iron absorption, fecal ferritin excretion, and blood indexes of iron status in women consuming controlled lactoovovegetarian diets for 8 wk. *Am J Clin Nutr*. (1999 May)

245. J R Hunt, Z K Roughead Adaptation of iron absorption in men consuming diets with high or low iron bioavailability. *Am J Clin Nutr*. (2000 Jan)

246. Armah SM, Boy E, Chen D, Candal P, Reddy MB Regular Consumption of a High-Phytate Diet Reduces the Inhibitory Effect of Phytate on Nonheme-Iron Absorption in Women with Suboptimal Iron Stores.. *J Nutr*. (2015 Aug)

247. Jingfang Liu, Qingxiu Li, Yaxian Yang, Lihua Ma Iron metabolism and type 2 diabetes mellitus: A meta-analysis and systematic review. *J Diabetes Investig*. (2020 Jul)

248. Xinhui Wang, Xuexian Fang, Wanru Zheng, Jiahui Zhou, Zijun Song, Mingqing Xu, Junxia Min, Fudi Wang Genetic Support of A Causal Relationship Between Iron Status and Type 2 Diabetes: A Mendelian Randomization Study. *J Clin Endocrinol Metab*. (2021 Oct 21)

249. Susana Puntarulo Iron, oxidative stress and human health. *Mol Aspects Med*. (Aug-Oct 2005)

250. Hansen JB, Moen IW, Mandrup-Poulsen T Iron: the hard player in diabetes pathophysiology.. *Acta Physiol (Oxf)*. (2014 Apr)

251. Voni Blesia, Vinood B Patel, Hisham Al-Obaidi, Derek Renshaw, Mohammed Gulrez Zariwala Excessive Iron Induces Oxidative Stress Promoting Cellular Perturbations and Insulin Secretory Dysfunction in MIN6 Beta Cells. *Cells*. (2021 May 9)

252. Sigurd Lenzen Oxidative stress: the vulnerable beta-cell. *Biochem Soc Trans*. (2008 Jun)

253. Piskin E, Cianciosi D, Gulec S, Tomas M, Capanoglu E Iron Absorption: Factors, Limitations, and Improvement Methods.. *ACS Omega*. (2022 Jun 21)

254. Anderson RL, Wolf WJ Compositional changes in trypsin inhibitors, phytic acid, saponins and isoflavones related to soybean processing. *J Nutr*. (1995 Mar)

255. 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)

256. Barzel US, Massey LK Excess dietary protein can adversely affect bone. *J Nutr*. (1998 Jun)

257. 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)

258. 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)

259. Shams-White MM, Chung M, Du M, Fu Z, Insogna KL, Karlsen 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)

260. 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)

261. Calvez J, Poupin N, Chesneau C, Lassale C, Tomé D Protein intake, calcium balance and health consequences. *Eur J Clin Nutr*. (2012 Mar)

262. Livingstone C Insulin-like growth factor-I (IGF-I) and clinical nutrition. *Clin Sci (Lond)*. (2013 Sep)

263. 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)

264. 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)

265. Wang H, Liu F, Yang L, Zu Y, Wang H, Qu S, Zhang Y Oxidative stability of fish oil supplemented with carnosic acid compared with synthetic antioxidants during long-term storage. *Food Chem*. (2011 Sep 1)

266. 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)

267. Trüeb RM Molecular mechanisms of androgenetic alopecia. *Exp Gerontol*. (2002 Aug-Sep)

268. 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)

269. 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)

270. 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)

271. 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)

272. 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)