MENNO HENSELMANS
Science to master your physique

MICRONUTRITION

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Contents

➢ Lecture

Micronutrition

Correctional notes: folate is once called vitamin B5 in the lecture. This should say B9. For vitamin C, units should be listed in mg, not mcg.

Multivitamins

It is difficult to discuss multivitamins without either writing a whole book on the subject or making gross generalizations, because the content of multivitamins varies considerably. We can say though that there is no need for a multivitamin if your diet is already good.

That's a big *if* though. Nutrient deficiencies are common, especially during weight loss diets, even in people that pay a lot of attention to their diet. Many strength trainees think if you eat a diet that mostly consists of whole foods, you're covered. You're not. Depending on which study you look at, over 50% of bodybuilders' diets are do not meet the recommended daily intakes of several micronutrients and that's not even taking into account their higher requirements compared to sedentary individuals [2, 3, 4, 5, 6]. As we'll discuss in the sections below on specific nutrients, bodybuilders, athletes and sedentary folk alike are all commonly deficient in one or more micronutrients. In fact, due to the lack of nutrients in modern food, if you take any random person off the street, it's highly unlikely that person has all micronutrients in the optimal range.

In a review of the prevalence of micronutrient deficiencies in popular diets, Calton (2010) concluded: "an individual following a popular diet plan as suggested, with food alone, has a high likelihood of becoming micronutrient deficient."

It can thus be reasonable to consume a multivitamin to make sure you cover all bases. The problem with this approach is that most multivitamins are absolute crap. A few of the common problems include:

- Most multivitamins employ cheap manufacturing methods that result in nutrients that are not bioavailable: the body cannot absorb them well. For example, most of the magnesium in multivitamins is magnesium oxide (see the section on magnesium below for more details).
- Most multivitamins only contain cheap isoforms, which results in poor bioavailability and worse, an imbalanced ratio of isoforms in the body. See the section on vitamin E for a common example.
- Most multivitamins massively overdose cheap nutrients that are easy to consume in your diet. Manufacturers do this because people and bodybuilders in particular are easily deceived by thinking more is better (while at the same time still being deficient in other micronutrients). Not only is this useless, over-supplementation can be harmful because many vitamins and minerals interact and overconsumption of one can cause deficiency of the other even in the presence of adequate intake. Many nutrients also act differently depending on the dosage.
- Most multivitamins lack micronutrients that many people are actually deficient in, such as vitamins D and K and the minerals calcium, magnesium, iron and iodine, because mega-dosing minerals can be toxic.
- Multivitamins often contain massive amounts of antioxidantsthat can interfere with the inflammatory signal for cell repair. (See the section on vitamin C and the Energy module's section on 'cut or bulk?'.)

All in all, the shotgun approach of indiscriminately taking a random multivitamin is likely to do more harm than good. Some research even finds that people taking multivitamins have a shorter life expectancy. As a rule of thumb, don't consume a multivitamin that has much more than 100% of the recommend daily intake of nutrients, unless you have a good reason. More specifically, you need to tailor your vitamin and mineral supplementation to your diet.

For those that don't care about their health, just their physique, it's worth noting that even the micronutrients without a direct relation to neuromuscular functioning can still impact the sensation of fatigue during strength training. It's often difficult to distinguish between physical health, mental health and optimal performance. "Mens sana in corpore sano." (A healthy mind in a healthy body.)

For best results, have bloodwork done. It's probably not more expensive than your last 6-month supply of supplements, infinitely more informative and it's certainly cheaper and healthier than using your multivitamin for life without knowing what it's doing. Not all micronutrient deficiencies can be assessed with bloodwork though, as we'll discuss below.

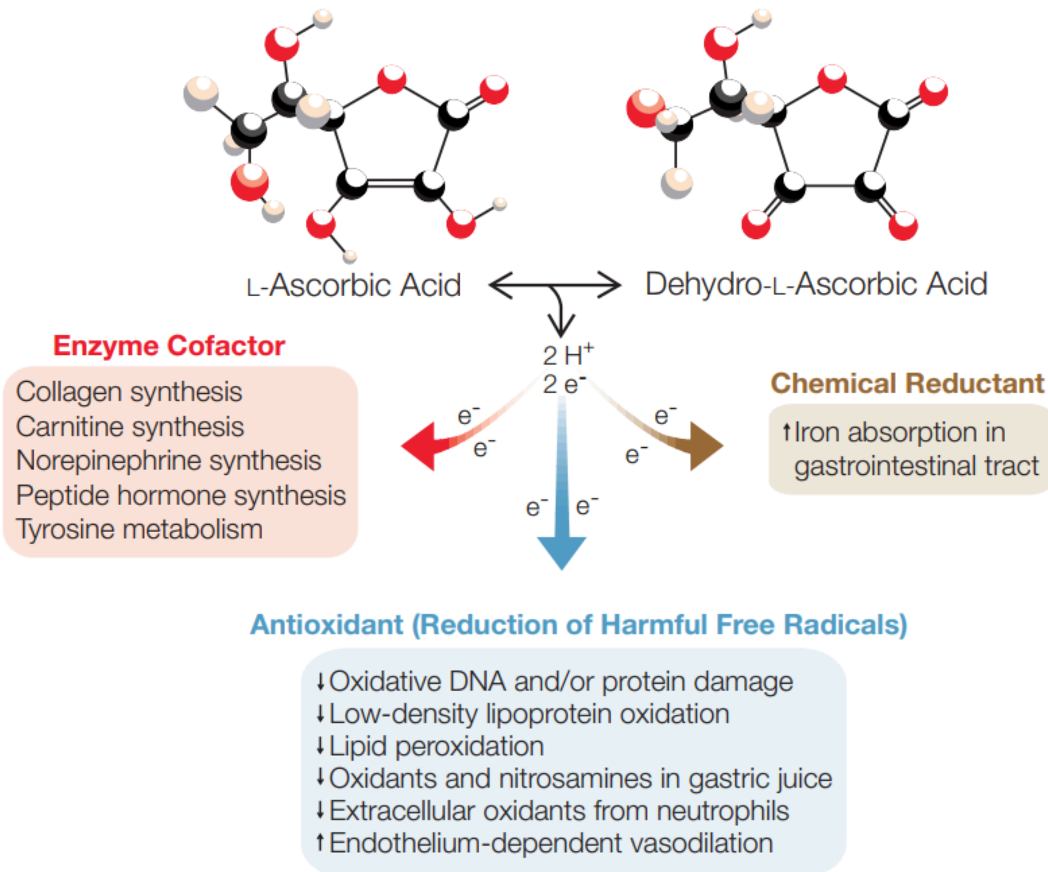
Let's dig into the micronutrients.

Vitamin C

Let's start with the celebrity of vitamins: vitamin C. Everyone knows you need it, but few people realize why. Vitamin C is a water-soluble antioxidant. It prevents free radical damage and oxidative stress, thereby keeping inflammation in check. This makes it very important for your immune system.

Vitamin C's antioxidant effect also gives vitamin C the lesser known ability of a reducing agent. What does a reducing agent do? Your body functions largely via chemical reactions. These chemical reactions are sped up by enzymes. Many of the enzymes catalyzing these various reactions contain a mineral cofactor, like copper or iron. Vitamin C functions as a reducing agent (antioxidant) to maintain the iron and copper atoms in the metalloenzymes in the reduced state. That may not sound like an impressive résumé, yet it makes vitamin C crucial to produce all the following compounds, which are needed for good connective tissue health, energy production and brain functioning:

- Collagen
- Carnitine
- Tyrosine
- Norepinephrine
- Serotonin



Actions of vitamin C. [Source]

How much do you need?

Vitamin C's Recommended Dietary Allowance (RDA) for adult men is 90 mg; 75 mg for women. These intakes are widely regarded as insufficient for optimal health, especially for strength trainees: it's better to consume 120-200 mg per day.

However, more is not always better. Inflammation is a natural part of muscle repair after exercise. Suppressing inflammation too much will thus directly sabotage the muscle growth process and your adaptations to exercise. Multiple studies have found that supplementing a gram or more of vitamin C considerably interferes with anabolic muscle signaling, strength development and muscle growth [2, 3]. Lower doses generally do not significantly affect exercise adaptations.

While vitamin C is virtually entirely non-toxic, daily intakes over a gram (from supplements) may also cause indirect health problems, such as hyperuricosuria, hyperoxaluria and hyperoxalemia. Healthy individuals should generally avoid supplementary doses over 250 mg.

Food sources of vitamin C primarily include fruits and vegetables. Excellent sources are asparagus, papaya, oranges, orange juice, cantaloupe, cauliflower, broccoli, brussels sprouts, green peppers, grapefruit, grapefruit juice, kale, lemons and strawberries.

Food	Amount	Vitamin C content
Strawberry, Oranges	1 cup	90 mg
Kiwi	Medium size fruit	75 mg
Cantaloupe	1 cup	68 mg
Banana	1 fruit	12 mg
Pineapple	1/2 cup	12 mg
Potato	1 small	40 mg

In practice, as long as your diet has several servings of plants on a daily basis, you should be covered for vitamin C. Only the poorest of diets tend to be deficient in vitamin C, so given the detrimental effects of excessive intake, healthy individuals should generally not supplement vitamin C.

Primary take-home message: Eat your fruits or veggies and you don't have to worry about vitamin C.

B-vitamins

B-vitamins are a class of related vitamins that function as co-factors or precursors (building blocks) for various metabolic processes, including energy production.

B number	Name(s)	Function
Vitamin B_1	thiamine	A coenzyme in the catabolism of sugars and amino acids.
Vitamin B_2	riboflavin	A precursor of cofactors called FAD and FMN, needed for flavoprotein enzyme reactions, including activation of other vitamins.
Vitamin B_3	niacin (nicotinic acid), nicotinamide riboside	A precursor of coenzymes called NAD and NADP, needed in many metabolic processes.
Vitamin B_5	pantothenic acid	A precursor of coenzyme A and therefore needed to metabolize many molecules.
Vitamin B_6	pyridoxine, pyridoxal, pyridoxamine	A coenzyme in many enzymatic reactions in metabolism.
Vitamin B_7	biotin, vitamin H	A coenzyme for carboxylase enzymes, needed for synthesis of fatty acids and in gluconeogenesis.
Vitamin B_8	(myo)-inositol	A non-essential pseudo-vitamin that acts as a second messenger in various tissues.
Vitamin B_9	folic acid, folate	A precursor needed to make, repair, and methylate DNA; a cofactor in various reactions; especially important in aiding

		rapid cell division and growth, such as in infancy and pregnancy.
Vitamin B_{12}	various cobalamins; commonly cyanocobalamin or methylcobalamin in vitamin supplements	A coenzyme involved in the metabolism of every cell of the human body, especially affecting DNA synthesis and regulation, but also fatty acid metabolism and amino acid metabolism.

Modified from Wikipedia.

How much do you need?

You generally don't need to bother with tracking your B-vitamin intake as a strength trainee, because B-vitamins are present in most whole foods and particularly animal protein sources. The name pantothenic acid (vitamin B5) comes from the Greek word *pantos*, meaning 'everywhere'. A high protein, whole food-based diet tends to result in adequate intakes of all B-vitamins.

There are 2 notable exceptions: vegetarians and pregnant women.

Pregnant women have a high requirement of folic acid, also known as folate or vitamin B9, because it's important for the neural development of the child. During pregnancy, folate requirements increase from 400 to 600 mcg per day. Since there's little toxicity risk, supplementing 200+ mcg per day is advisable if you're not completely sure you're getting this intake during pregnancy.

Vegetarians are at notorious risk for vitamin B deficiency, especially B12. Vitamin B12 is practically only found in animal foods, which have derived their cobalamins from micro-organisms. Any vitamin B12 found in plant foods can likely be traced either to contamination with microorganisms from manure (yes, shit) or, in the case of legumes, to the presence of nitrogen-fixing bacteria in the plant root nodules. The RDA for adults for vitamin B12 is 2.4 µg per day, but 4 µg per day may be better for optimal health.

Food	Amount	Vitamin B12 content
Clams	3 oz.	84 µg (!)
Oysters	3 oz.	30 µg (!)
Salmon	3 oz.	2.6 µg
Beef steak	3 oz.	1.35 µg
Milk	1 cup	1.0 µg
Cod	3 oz.	0.9 µg
Yogurt	1 cup	0.9 µg
Cottage cheese	½ cup	0.7 µg
Pork loin	3 oz.	0.65 µg
Eggs	1	0.6 µg
Poultry	3 oz.	0.28 µg

Note: µg = mcg = microgram = 1/1,000 mg = 1/1,000,000 gram

As you can see in the above table, even lacto-ovo vegetarians can have a hard time consuming enough vitamin B12. Consuming enough vitamin B12 is further complicated by the need to consume it frequently, because its oral bioavailability decreases dramatically above intakes of 2 mcg. Your body absorbs only ~13 mcg of a 1,000 mcg intake. The form of vitamin B12 supplementation doesn't matter: bioavailability of all popular forms, including cyanocobalamin, is similar.

In contrast to most nutrients, vitamin B12's bioavailability is even lower when taken with a meal, so it's better to consume vitamin B12 supplements fasted. Due to the low and highly variable bioavailability of oral vitamin B12, many doctors prefer intramuscular injections to correct deficiency.

Fortunately, vitamin B12 is exceptional as a water-soluble vitamin in that the body has around 2,500 mcg of it bound as co-factors to enzymes, mostly in the liver. This is not ‘storage’ in the traditional sense because the vitamin B12 is actively in use and not in a reserve compartment for later use. Since the daily requirement is low relative to total body ‘stores’, deficiency typically takes years to develop, but once developed, it’s hard to treat without injections.

B-vitamins have no known toxicity mechanism even at very high intakes. They are water soluble and thus easily excreted in the urine. Considering that B-vitamin complexes are cheap, vegetarians should supplement a daily B-vitamin complex with at least 100% of the RDI of all B-vitamins and 4 mcg of vitamin B12. However, some weak epidemiological research finds associations between high vitamin B12 levels and all-cause mortality, so don’t supplement more than you need and don’t supplement it if you consume enough animal foods in your diet.

You can diagnose vitamin B12 deficiency with bloodwork. However, sufficient serum vitamin B12 does not guarantee sufficient intracellular levels, so you also need to check for elevated methylmalonic acid and serum homocysteine level levels. Vitamin B12 deficiency normally causes methylmalonic acid (MMA) and homocysteine to accumulate, as they rely on vitamin B12 to be metabolized. Homocysteine conversion can also rely on other B-vitamins as co-factors, however.

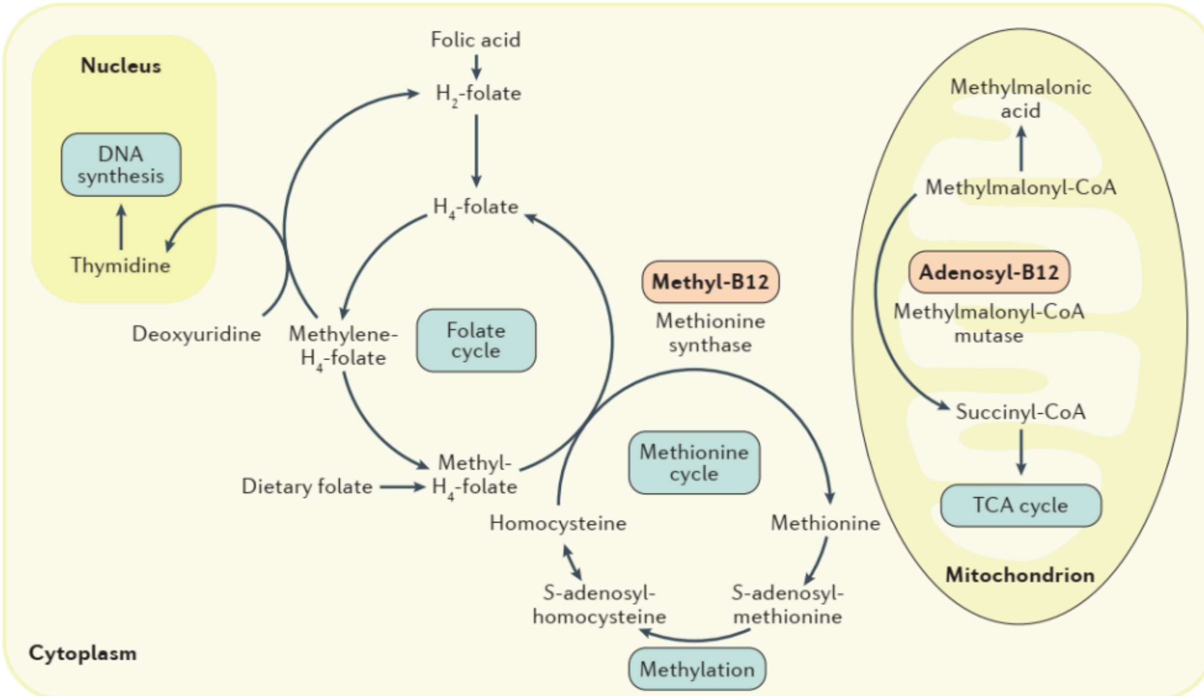


Figure 1 | **Vitamin B_{12} and folate metabolism and function.** Vitamin B_{12} (B12) and folate are required for the methionine synthase reaction in which a methyl group is transferred from methyltetrahydrofolate (methyl-H_4-folate; also known as levomefolic acid) to homocysteine by methionine synthase, with methyl-B12 as a coenzyme to form methionine. The resulting H_4-folate can then be returned to the folate pool and made available for the generation of methylene-H_4-folate, the form required for *de novo* synthesis of thymidine, which is essential for DNA replication and repair. Hence, either folate or B12 deficiency results in the same biochemical perturbation in thymidine synthesis and DNA replication. In the case of B12 deficiency, folate is 'trapped' in the unusable methyl-form[5,194]. B12 is also involved in the conversion of methylmalonyl-CoA (methylmalonic acid bound to coenzyme A) to succinyl-CoA by the enzyme methylmalonyl-CoA mutase with adenosyl-B12 as a cofactor; succinyl-CoA is a major intermediary of the tricarboxylic acid (TCA) cycle. In B12 deficiency, substrates of both B12-dependent reactions accumulate, which leads to increased levels of methylmalonic acid and homocysteine in the plasma. A combination of low levels of B12 and increased levels of folate was associated with higher concentrations of methylmalonic acid and total plasma homocysteine[156,157]. Major complications of B12 deficiency are megaloblastic anaemia, as a result of inhibition of DNA synthesis, and neurological manifestations.

The relation between Vitamin B12, folate, methionine, homocysteine and MMA. Source

Primary take-home message: A high protein diet from whole foods inherently takes care of B-vitamin requirements normally, except for vegetarians and pregnant women. Vegetarians should generally supplement a B-vitamin complex including 4+ mcg vitamin B12. Pregnant women should generally supplement 200+ mcg folate.

Vitamin A and carotenoids

Vitamin A, also called preformed vitamin A or retinoid, refers to a whole group of compounds that possess the biological activity of all-trans retinol.

Vitamin A is closely related to carotenoids, often referred to as provitamin A, which represent a group of compounds that are precursors of vitamin A. However, only a minority of carotenoids convert to retinol and exhibit vitamin A activity. A popular carotenoid is β-carotene.

Vitamin A is essential for vision as well as for cellular differentiation, growth, reproduction, bone development and immune system functions. Carotenoids also function as antioxidants.

Vitamin A and carotenoids interact with vitamins E and K. Excess vitamin A intake interferes with vitamin K absorption. High β-carotene intake may decrease plasma vitamin E concentrations.

How much do you need?

Recommendations for vitamin A intake are expressed as retinol activity equivalents (RAE) to account for differences in the biological activities of the carotenoids.

Population	Vitamin A RDA
Adult men	900 µg RAE (3,000 IU)
Adult women	700 µg RAE (2,310 IU)
Lactating women	1,300 µg RAE (4,300 IU)

Vitamin A is primarily found in animal foods, especially liver. Carotenoids are more commonly available in plants. They are part of the pigments that give plants their yellow, orange and red colors, so these colored plants tend to be high in carotenoids. A high intake of carotenoids will also give your skin a yellow tint.

Food	Amount	Vitamin A content (RAE)
Beef liver	3 oz.	22,000 IU (6,600 µg)
Herring	3 oz.	731 IU (220 µg)
Milk	1 cup	500 IU (150 µg)
Egg	1	280 IU (84 µg)
Cheddar cheese	1 oz.	200 IU (60 µg)
Sardines	3 oz.	92 IU (27.6 µg)
Tuna	3 oz	55 IU (16.5 µg)

Food	Amount	β-carotene content (RAE)
Spinach	½ cup cooked	5,660 IU (472 µg)
Carrots	½ vegetable	4,550 IU (379 µg)
Cantaloupe	½ cup	1,616 IU (135 µg)
Broccoli	½ cup cooked	725 IU (60 µg)
Peas	½ cup cooked	600 IU (50 µg)
Squash	1 cup cooked	136 IU (11 µg)

Vitamin A and carotenoids are lipid-soluble, so their absorption is higher in fatty meals.

In general, a high protein, fibrous, whole foods-based diet should easily result in adequate vitamin A activity and there is no need for supplementation.

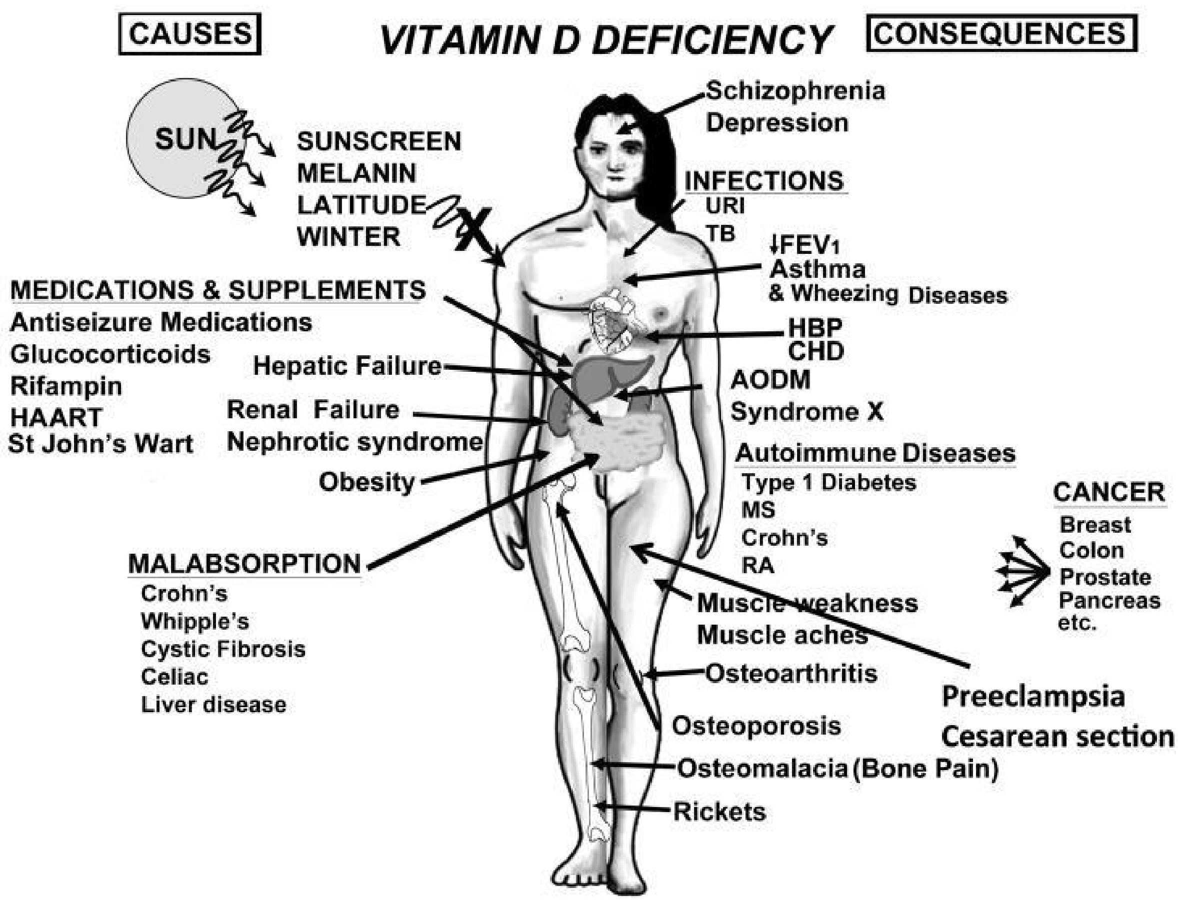
Toxicity is rare but can be a concern if you regularly consume liver or supplement large amounts of cod liver fish oil. The Tolerable Upper Intake Level (UL) for preformed vitamin A is 3,000 µg RAE (10,000 IU) per day. Ingesting larger amounts (such as 50,000 IU) of vitamin A in a single meal may result in acute hypervitaminosis A. Symptoms of acute hypervitaminosis A include nausea, vomiting, double or blurred vision, increased intracranial pressure, headache, dizziness, skin desquamation and muscle incoordination. Chronic intake of doses between 10,000 IU - 50,000 IU of vitamin A (e.g. more than recommended amounts) can also lead to hypervitaminosis A.

Carotenoids, in contrast to vitamin A, appear to have few side effects. The most commonly cited problem with supplemental carotenoid use is hypercarotenosis, also called carotenodermia; this problem is most often seen in people ingesting over 30 mg of β-carotene daily for weeks to months. Hypercarotenosis results in a yellow discoloration of the skin, especially in the fat pads or fatty areas of the palms of the hands and soles of the feet. It's harmless and can even make you look extra healthy, up to a point. No Tolerable Upper Intake Level has been established for β-carotene or other carotenoids.

Primary take-home message: Both fatty protein sources and vegetables are rich in (pro-)vitamin A, so any kind of whole foods diet typically covers vitamin A requirements.

Vitamin D

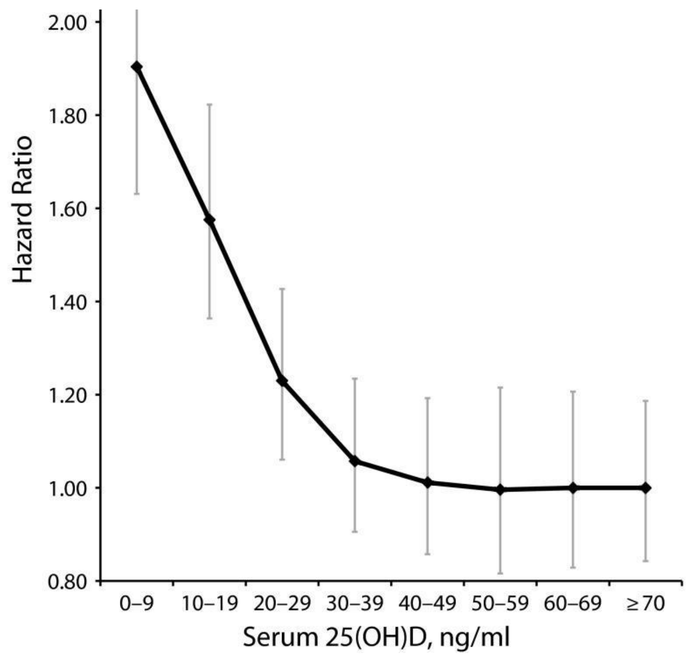
Vitamin D3 (cholecalciferol) is a fat-soluble pro-hormone and an essential vitamin. It's produced naturally by the skin after exposure to ultraviolet radiation, particularly UVB, like in sunlight. It is important for strength trainees, because it is necessary for optimal bone strength, mineral metabolism, immune function, neuromuscular functioning and testosterone synthesis. As a result, your vitamin D level can significantly influence your strength development [2, 3, 4], your lean body mass [2] and your injury resistance, although the direct short-term benefits for your gains of vitamin D supplementation are not consistent, even when you're deficient. Getting enough vitamin D can also improve sleep quality.



How much do you need?

Vitamin D requirements have been colossally underestimated by public health authorities for a long time, comprising what is now widely regarded as one of the most damaging mistakes in public health advice. Many public health institutes recommend daily vitamin D3 intakes of only 400-600 IUs with deficiency being diagnosed only below a serum 25-hydroxyvitamin D level of 20-30 nmol/l. Meta-analytic research finds all-cause mortality decreases up to 50 nmol/l and many organizations define 50 as the minimum these days, so that should be the minimum target. After this point, more vitamin D supplementation generally doesn't have significant health benefits and won't further improve your gains [2, 3, 4]. Still, some research finds health benefits up to 100 nmol/l, especially for specific diseases and conditions, and some researchers recommend aiming for a vitamin D3 level of 100 nmol/l [2]. Benefits could theoretically increase up to a serum 25-hydroxyvitamin D level of ~115 nmol/l. This is the level found in traditional hunter-gatherer societies. After this point, almost all vitamin D is placed in storage or even destroyed, suggesting it's as much as the body can use.

Note that bloodwork normally tests 25-hydroxyvitamin D, not vitamin D3 directly and especially not vitamin D2. Both vitamin D forms are converted to 25-hydroxyvitamin D (25(OH)D or Calcidiol) in the liver. 25-hydroxyvitamin D is a stable form that aggregates the effect of both vitamin D forms. It's not the biologically active form in the body though. 25-hydroxyvitamin D is converted to 1,25-hydroxyvitamin D (calcitriol) in the kidneys and that's the form that interacts with vitamin D receptors.



Overall age-adjusted hazard ratios for all-cause mortality in 32 studies of serum 25-hydroxyvitamin D: 1966–2013. 1 ng/ml = 2.496 nmol/l. Source

You can generally achieve an optimal serum vitamin D concentration with 10-30 minutes of daily near-full-body sun exposure with a UV index of at least 3. The exact time required depends on how dark someone's skin is. The darker someone's skin, the more sun exposure they need. The sun exposure needs to be direct, because glass and sunscreen block ultraviolet radiation. Tanning beds are also effective, but since they consist of ~95% UVA instead of B, you need relatively more radiation to achieve the same vitamin D biosynthesis.

Since virtually the entire population in Northern countries sees little strong sunlight and there is very little vitamin D in food (anyone saying any food is a good source of vitamin D is clueless), this means almost everyone benefits from supplementation. Even most *outdoor* athlete populations have a deficiency prevalence of over 44%, not to mention the percentage with a suboptimal level.

Health authorities commonly advise that you need 400-600 IUs per day for good serum vitamin D status. However, a corrected analysis of the data used by the Institute of Medicine found that 8895 IU per day was needed for 97.5% of individuals to achieve values ≥ 50 nmol/L. Heaney et al. (2015) confirmed the mistake, reporting that intakes of 3875, 6201 and 9122 IU per day are needed to get serum 25(OH)D values of 50, 75, and 100 nmol/L, respectively. In contrast, a meta-analysis by Cashman et al. (2017) estimated an intake of 1040 IU per day was sufficient to maintain vitamin D3 levels over 50 nmol/L. However, a subsequent one-year RCT by Bacha et al. (2021) found 3750 IU per day resulted in levels of 90 nmol/L, regardless of sex, age or BMI, replicating similar results from Shirvani et al. (2019), Gallagher et al. (2012) and Heaney et al. (2003) that indicated the optimal vitamin D3 intake is around 4000 IU per day.

Overall, nearly all untanned individuals are advised to supplement at least 1000 IUs vitamin D3 per day, going up to 9000 IUs per day depending on sun exposure, bodyweight, skin type and diet quality. A good general vitamin D3 supplementation dose is 4000 IU per day. This dosage virtually never results in toxicity while ensuring sufficient levels in the vast majority of the population.

You can take a lot more initially, up to 20k IUs, to build up serum levels more rapidly. If you forget to supplement for a day or a period, you can also catch up later, since the body can produce and handle thousands of IUs itself during prolonged exposure to sunlight.

There is very little risk associated with mega-dosing vitamin D. However, supplementation can lead to excess vitamin D levels because it circumvents the negative feedback loop of natural vitamin D production. Vitamin D intoxication only reliably occurs when serum levels exceed 200 ng/mL 25(OH)D though, which generally requires 20k+ IUs of vitamin D3 supplementation.

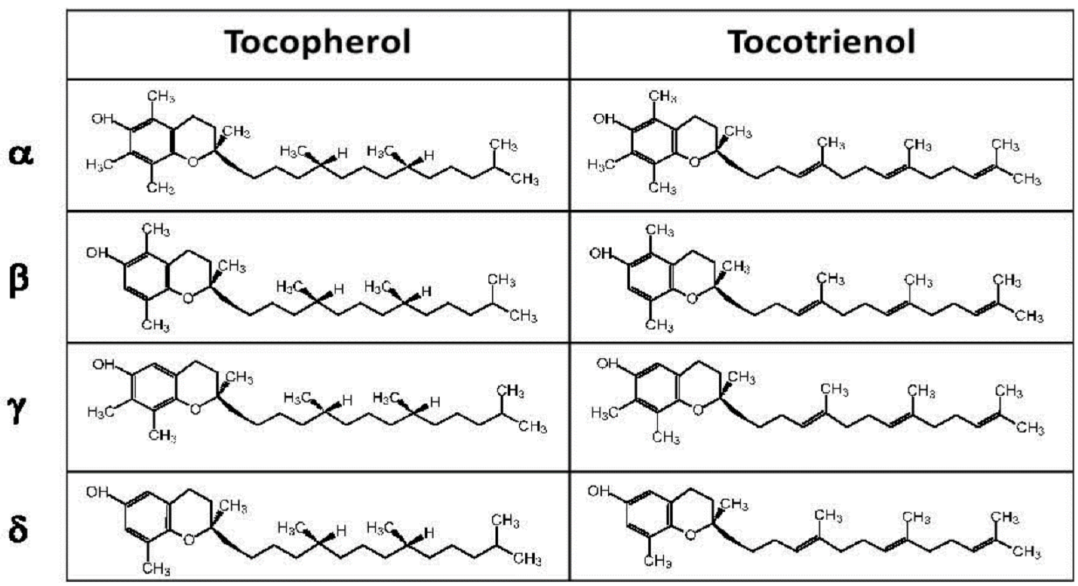
Since vitamin D is fat soluble, you should consume it with a meal with fats.

Vitamin D2 is not very bio-effective in animals, so it is a poor choice of supplementation.

Primary take-home message: Unless you get enough sun exposure to maintain a tan, you should supplement vitamin D3 for the wide range of potential benefits, even if they're small.

Vitamin E

Vitamin E is an antioxidant. It plays important roles in cell membranes and cell signaling. Unbeknownst to many people, vitamin E is not just a single compound. Many multivitamins only include alpha-tocopherol, because many people think this is vitamin E. In fact, [vitamin E has 8 isoforms/vitamers (alpha to delta isoforms of 4 tocopherols and 4 trocotrienols) with different functions. Over-supplementation of one of them causes competitive uptake inhibition of the others, potentially causing a deficiency and imbalance of the isoforms in the body].



The 8 vitamers of vitamin E. [Source]

Most vitamin E supplements only contain the alpha isomer. [Very high levels of the alpha isomer in the body have been associated with increased cardiovascular disease in multiple studies], so more is definitely not better when it comes to vitamin E.

Plus, [synthetic vitamin E is only 74% as bioavailable as the vitamin E found in food]. In other words, the body absorbs 26% less vitamin E when it comes from a supplement instead of whole foods.

Doses upward of 235 mg of vitamin E may impair training adaptations [2, 3], including muscle growth, by excessively suppressing inflammation, especially but not exclusively when combined with high-dose vitamin C supplementation. Lower doses generally do not significantly affect exercise adaptations.

How much do you need?

Recommendations for vitamin E are based upon intake of the natural form (RRR) of α-tocopherol. The RDA for vitamin E for adults is 15 mg (22.4 IU) of RRR α-tocopherol. During lactation, recommendations are slightly higher at 19 mg (28.4 IU).

Vitamin E, in its various forms, is found primarily in plant foods, especially the oils in nuts. Green vegetables are also rich in vitamin E. As a fat-soluble vitamin, vitamin E's absorption is much higher in a fatty meal.

Food	Amount	α-tocopherol content
Almonds	1 oz.	7.0 mg
Hazelnuts	1 oz.	4.3 mg
Peanuts	1 oz.	2.2 mg
Spinach	½ cup, cooked	1.9 mg
Broccoli	½ cup, cooked	1.2 mg

Vitamin E deficiency is rare. A whole foods-based diet with green vegetables should ensure adequate vitamin E status. Deficiency can be diagnosed with bloodwork: a serum alpha-tocopherol level below 5 mcg/mL strongly indicates vitamin E deficiency.

Primary take-home message: As long as your diet has enough fats and green veggies, or lots of plants in general, you shouldn't have to worry about vitamin E. Supplementation is more likely to be harmful than helpful.

Vitamin K

Vitamin K is required to form coagulation factors. Without those, your blood won't clot effectively and you will easily bruise and bleed excessively. Vitamin K also interacts with vitamin D and calcium during bone formation.

Although intestinal bacteria can produce compounds with vitamin K activity, they generally don't maintain adequate vitamin K status, so you need to consume vitamin K in your diet.

How much do you need?

The daily Adequate Intake for vitamin K has been set at 120 mcg for men and 90 mcg for women or a more conservative 1 mcg per kilogram bodyweight.

Vitamin K content per 100 g of food			
>200 µg	>100 µg	10-50 µg	<10 µg
Broccoli, kale, swiss chard, turnips, watercress greens, collards, spinach, salad greens	Cabbage, lettuce, Brussels sprouts, mustard greens	Asparagus, celery, green beans, avocado, kiwi, pumpkin, peas, peanut butter, lentils, kidney beans, soybeans	Milk, butter, eggs, cheese, meats, fish, corn, cauliflower, grains, fruits (most)

Unbeknownst to many, there are 2 natural forms of vitamin K: K1 (phylloquinone) and K2 (menaquinone).

- Vitamin K1 is found in plants and is commonly the primary source of vitamin K in the diet.
- Vitamin K2 is produced by bacteria in foods such as cheese and natto.

Vegetables, particularly green leafy vegetables, are the richest source of dietary vitamin K in the form of vitamin K1 (phylloquinone).

Vitamin K2 (menaquinone) is present in large amounts specifically in fermented foods like aged cheese, as it is created by bacteria. Bacteria in your intestines can convert vitamin K1 to K2, so conventional advice holds that you don't need vitamin K2 in your diet. However, in epidemiological research, vitamin K2 but not vitamin K1 intake is strongly inversely related to all-cause mortality.

Problematically, vitamin K deficiency is difficult to diagnose. Bloodwork can only show vitamin K levels in serum, not the vitamin K in the intestines. So doctors commonly test vitamin K deficiency by seeing how long it takes for your blood to clot. Yet lack of clinical blood clotting problems does not necessarily guarantee maximal health benefits.

While vitamin K is a fat-soluble vitamin, the body does not retain it very effectively, so you need to consume it at least once a week and ideally every day to prevent deficiency.

To get 100 mcg of vitamin K, you'd need to consume green leafy vegetables, fermented foods or any of the following on a daily basis:

- 2.5 cups of pumpkin
- ~4 cups of pomegranate juice
- 170 g of pine nuts or almost 300 g of cashews
- 3 cups of blueberries
- 4.5 cups of grapes
- 2 avocados (roughly a pound)

Without those, you may need to supplement vitamin K1 and/or 2. There is virtually no risk of vitamin K toxicity, so supplementation is safe. You can supplement vitamin K1 in the form of phylloquinone and vitamin K2 in the form of menaquinones (MK-4, MK-7, MK-8 or MK-9). Since vitamin K is fat soluble, for effective absorption you need to consume it with a fatty meal.

Primary take-home message: To get enough vitamin K, you practically have to eat fermented foods, starchy vegetables or a lot of whole foods. Deficiency risk for bro diets rich in grains and low in veggies is significant.

Sodium

What most people call 'salt' or 'table salt' is chemically termed sodium chloride (NaCl). It's 40% sodium (Na) and 60% chloride (Cl). Certain varieties of salt, like Himalayan sea salt, also contain trace amounts of other minerals, and have some color, often a pinkish glow. This is the result of reduced processing, as salt is produced by evaporating (sea) water.

Sodium is an essential mineral for humans. It's a key electrolyte in the body that helps us maintain fluid balance in various tissues. Sodium attracts water, so a tissue's sodium concentration is a key determinant of its fluid level.

When salt became commercially available on a large scale in the West, it quickly became enormously popular. Salt not only increases the flavor of food to a completely different level, it also serves as a food preservative due to its anti-microbial function. To illustrate salt's historic importance, the word 'salary' comes from the Latin 'salarium', as Roman soldiers primarily used their salary to buy salt. Sometimes they were even paid directly in salt. Gandhi said: "next to water and air, salt is perhaps the most vital to health".

But salt's reputation as "This stuff's too good to be true" has taken a turn for the worse. These days, most people's knowledge of salt goes no further than: "It's unhealthy, right?" Salt's notoriety is fueled by many government organizations. According to multiple health organizations, including the American Heart Association, most of the population would be best served to reduce their sodium intake to < 1500 mg per day to improve health parameters and prevent the onset of disease. This includes adults above 'middle age' (45 – 65 years), all African Americans and anyone with hypertension. The remaining population is advised to keep their daily intake below 2,300 mg. This would be bad news, because many people that don't actively monitor their sodium intake end up with a sodium intake of at least 3 grams a day, often twice as much as the official recommendation.

Should we all start becoming more sparing with our salt and accept blander food?

It's true that a high sodium intake has been associated with increased blood pressure, cardiovascular disease (CVD) and stroke. However, much of the research on health effects comes from epidemiology: it's cross-sectional, observational research, with less support from the scientific gold standard: randomized controlled trials. Since it's primarily highly processed junk foods that have very high amounts of sodium, correlations in observational research beg the question if it's actually the sodium intake in the diet and not just the overall diet that puts these individuals at an increased risk of heart-related incidents.

Unfortunately, many organizations rely on expert opinion (level C) rather than hard data for their sodium intake recommendations. The bulk of the actual evidence to avoid sodium relies on the finding that a high sodium intake increases your blood pressure. Blood pressure is widely known as a silent killer, as it can lead to cardiovascular disease with few warning symptoms. Hypertension, the term for high blood pressure, increases the strain on your blood vessels and heart, and can thereby cause cardiovascular disease. A 2013 meta-analysis, confirmed by a 2020 meta-analysis, found that salt reduction by ~4.4 g per day leads to reduction in blood pressure of 4 mm Hg for systolic blood pressure and 2 mm Hg for diastolic blood pressure. Systolic blood pressure refers to the top pressure while the heart's contracting and pumping the blood through your arteries. Diastolic blood pressure refers to the pressure when the heart relaxes and fills with blood in between beats.

The exact blood pressure reduction from a reduced sodium intake varies significantly per person. The blood pressure reduction tends to be greater in individuals with higher blood pressure. Some people have very low 'salt sensitivity': they do not experience an increase in blood pressure from high-sodium diets. On average though, salt restriction does reduce blood pressure in the population. The next question is: how practically meaningful is this reduction for your health?

Whether the blood pressure reduction from a lower sodium intake is beneficial for you depends on your current blood pressure. For the average American, lowering their sodium intake is probably a good idea. A 2022 meta-analysis found that on average in the literature, switching from standard table salt (sodium chloride) to a salt substitute like potassium chloride reduced blood pressure and all-cause mortality considerably. Most people find potassium chloride to be less tasty and more bitter than regular salt, so going sodium-free is a big sacrifice. Importantly, many studies were on overweight, non-exercising, hypertensive individuals. Most official guidelines call systolic blood pressure normal when it's below 120 or 130 mm Hg and diastolic blood pressure is below 80 or 85 mm Hg (see below). So the blood pressure reduction that can be achieved by salt restriction is about one fifth of the interval defining each blood pressure category.

ACC/AHA				ESC/ESH			
Category	**SBP**		**DBP**	**Category**	**SBP**		**DBP**
Normal	< 120	and	< 80	Optimal	< 120	and	< 80
Elevated	120–129	and	< 80	Normal	120–129	and/or	80–84
Stage 1 hypertension	130–139	or	80–89	High-normal	130–139	and/or	85–89
Stage 2 hypertension	≥ 140	or	≥ 90	Grade 1 hypertension	140–159	and/or	90–99
				Grade 2 hypertension	160–179	and/or	100–109
				Grade 3 hypertension	≥ 180	and/or	≥ 110
				Isolated systolic hypertension	≥ 140	and	< 90

Official blood pressure categorization guidelines from the American College of Cardiology (ACC), the American Heart Association (AHA), the European Society of Cardiology (ESC) and the European Society of Hypertension (ESH). SBP = systolic blood pressure. DBP = diastolic blood pressure. Source

As a lean, exercising individual, the absolute risk reduction from lowering your blood pressure within the normal range is minor. A 2019 meta-analysis found that the decrease in blood pressure from sodium restriction is only clinically relevant for individuals with a blood pressure over 131/78 mm Hg systolic/diastolic. For individuals with normal blood pressure, sodium restriction only offers a small reduction in blood pressure that's unlikely to affect their overall mortality or longevity. The increase in blood pressure from a high sodium diet does not consistently translate into an increase in cardiovascular health incidents. A 2014 Cochrane systematic review of the randomized controlled trials found "no strong evidence that dietary advice or substitution to reduce salt intake reduced all-cause mortality" in people with normal blood pressure. Even in hypertensive individuals, the evidence for clinically meaningful benefits was weak. This conclusion was unchanged from the 2011 systematic Cochrane review on salt restriction's health effects and the famous NHANES I large-scale observational study. Several review papers have directly contradicted the common official low salt dietary recommendation [1, 2].

Moreover, excessively low sodium intakes may be harmful. Low sodium intakes activate the renin-angiotensin-aldosterone system (RAAS) and the sympathetic nervous system in general. This effectively creates a stress response and can create similar problems as chronic stress. Many studies have documented adverse health effects of very low sodium intakes. In the NHANES II follow-up study, there was an *inverse* relation between sodium intake and both cardiovascular disease (CVD) mortality and all-cause mortality, a finding replicated in a 2020 cross-sectional review of 181 countries by Messerli et al: people with a low sodium intake were at an *increased* risk of dying from any cause and heart-related causes in particular. Specifically, individuals who consumed less than 2.3 g sodium per day had a 37% higher CVD mortality and 28% higher all-cause mortality than those who consumed more sodium. Another prospective population study supported that lower sodium intake is associated with higher CVD mortality. In fact, many other studies have found serious negative health consequences of restricting sodium intake to the low levels recommended by many governments.

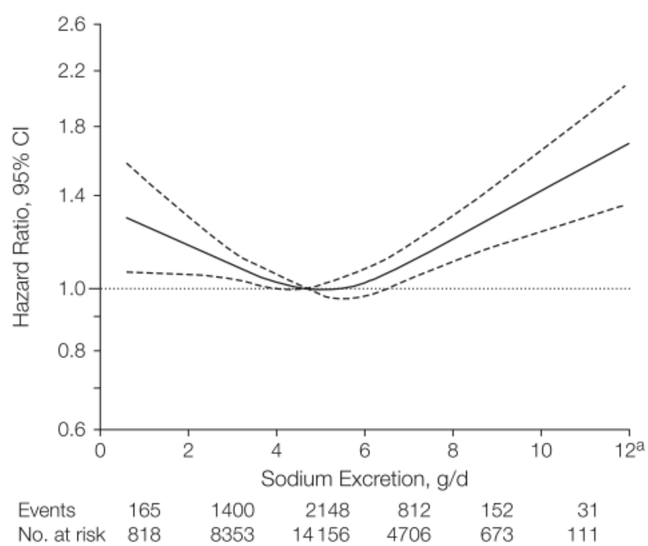
- Increased serum inflammation levels and deterioration of kidney functioning in heart failure patients.
- Increased heart rate and resting sympathetic activity (fight-or-flight-response) in healthy adults.
- Increased insulin resistance [2, 3, 4, 5] through activation of the renin-angiotensin-aldosterone and sympathetic nervous systems. Low salt diets have been reported to increase serum aldosterone and plasma noradrenaline concentration by at least 4-5-fold compared to a higher salt diet. In one research study, dietary sodium restriction was associated with a median 15% reduction in insulin sensitivity. Not only a severe, but already a moderate salt reduction from 5.4 g to 1.7 g sodium per day aggravates both systemic and vascular insulin resistance. The aldosterone increase on a very low sodium diet is accompanied

by a drastic reduction (up to 22-fold) in urinary sodium excretion in order to keep serum sodium levels constant.

- Hyponatremia, a condition in which serum sodium sinks to life-threatening levels.

In conclusion, there is an optimum level of sodium intake, not a maximum. Less sodium certainly isn't always better for your health. The sodium sweet spot (no pun intended) for cardiovascular health appears to be around 3-5 grams per day (see graph below) [2, 3, 4, 5]. This range is almost exactly in line with how much sodium people naturally end up consuming on average. The average sodium intake of the population is remarkably stable over time and across societies: "2.6–5 g per day is a mean intake that has been recorded consistently over 5 decades, across 45 countries, and in multiple ethnic groups." [2]

Figure 1. Estimated 24-Hour Urinary Excretion of Sodium and Composite of Cardiovascular Death, Stroke, Myocardial Infarction, and Hospitalization for Congestive Heart Failure



Sodium intake has an optimum curve relation with health: too low and too high intakes can both be harmful.

Exercise greatly increases sodium requirements: aerobic exercise in the heat can cause sodium losses in sweat of up to 5.5 grams of sodium per hour(!) A regular indoor strength training workout tends to cause 1-2 grams of sodium loss. Thus, exercising individuals have significantly higher sodium requirements than sedentary individuals.

Individuals with high blood pressure, heart failure or chronic kidney disease are much more likely to benefit from sodium restriction. Such clinical cases should obviously be discussed with a specialist. Blood pressure medication can be very effective with an excellent safety profile and practically no major side-effects, so they may even be preferable over a very strict low-sodium diet. Exercising individuals are generally recommended diuretics or angiotensin-converting enzyme (ACE) inhibitors as first-line treatment.

How much do you need?

In conclusion, sodium restriction for healthy strength trainees is more likely to be harmful than helpful. Strength trainees' sodium requirements for optimal health are likely in the range of 5-7 grams per day on training days and 3-5 g per day on rest days, far higher than many governments recommend. If you consume salt to taste without any restriction and avoid very high sodium junk foods, your sodium intake should naturally end up in the ideal range and there is no need to obsess over your exact sodium intake. Do check your blood pressure at least annually to see it's still in the normal range. If not, sodium restriction or blood pressure medication might be warranted.

Primary take-home message: In the context of a whole foods-based diet for a healthy, exercising individual, you can enjoy your salt to taste. Just keep an eye on your blood pressure periodically to make sure it's in the healthy range.

Potassium

Potassium is an essential mineral. The average body stores 200-300 g of potassium, almost all within cells, which functions as an electrolyte essential for our survival. Together with sodium, which is found mainly in extracellular space, notably plasma, potassium regulates your body's fluid volumes by forming electrochemical gradients. These gradients are also needed for nerve transmission, muscular contractions, blood pressure regulation and kidney functioning. You also need potassium for good calcium absorption, insulin secretion and to maintain acid-base balance.

How much do you need?

The Adequate Intake of potassium is 4.7 grams per day for adults. Deficiency is relatively common in the general population. Your kidneys are extremely proficient at regulating potassium excretion, however, which gives you great flexibility for your daily intake and circumvents any toxicity risk for healthy individuals. A small amount of potassium will always be lost in the urine, stool and sweat, which makes potassium an essential micronutrient, but it's easy to consume enough of it, **if** your diet's any good, as potassium is found in almost all whole foods, notably animal and fish flesh, fruit and vegetables, as well as dairy, tea and coffee. As such, any whole food-based diet generally maintains sufficient potassium levels and neither deficiency or toxicity are a common concern.

Food	Amount	Potassium content
Potato	1 medium	610 mg
Banana	1 medium	422 mg
1% Milk	1 cup	366 mg
Spinach, raw	2 cups	334 mg
Chicken breast, grilled	3 ounces	332 mg
Rice, brown, cooked	1 cup	154 mg
Coffee	1 cup	116 mg

Vomiting, diarrhea and diuretic use notably increase potassium excretion and thereby the risk of potassium deficiency (hypokalemia). Symptoms include malaise, constipation, muscle weakness and fatigue. Potassium supplementation can prevent this, but above ~100 mg, digestive problems often result from supplementation, which largely defeats their purpose, especially since it's primarily digestive problems that give rise to potassium deficiency. Potassium supplementation is also risky because of its large amounts and rapid absorption, which can be lethal in certain cases. As such, potassium supplementation above 100 mg per day is generally inadvisable.

Since almost all potassium stores are intracellular, bloodwork is nearly useless to diagnose potassium deficiency. Body potassium balance can be calculated by monitoring intake and excretion, but this is rarely done outside of experiments.

Primary take-home message: Adequate potassium intake requires consuming a lot of whole foods. It doesn't matter so much which ones, as long as it's a lot of them. Bro diets rich in grains and low in veggies are at significant risk of suboptimal intakes.

Chloride

Chloride is an essential mineral that functions as an electrolyte. It's almost exclusively consumed along with sodium in table salt (sodium chloride with 60% chloride). Its negative charge offsets the positive charge of sodium. From consumption to function, chloride goes hand in hand with sodium. Chloride is found in similar amounts in similar locations as sodium, is absorbed similarly and has the same Adequate Intake and Upper Tolerable Intake as sodium in mmol. The AI is 2.3 g and the UTI is 3.6 g, but as per the section on sodium, the UTI can be strongly contested. You can think of chloride as sodium's negative brother and for practical purposes, as long as your sodium intake is ok, so is your chloride intake.

Bloodwork can measure chloride concentration in the serum, but like with sodium, solute levels are strongly dependent on hydration status, so a test requires being optimally hydrated and for a definitive diagnosis, a method known as coulometric titration is needed.

Primary take-home message: As long as your sodium intake is under control, your chloride intake will be as well.

Calcium

Calcium is the most common mineral in the body, 99% of which is in your bones. Calcium is required for neuromuscular functioning, satiety signaling, the regulation of blood flow, bone health and a host of other processes. Athletes that consume more calcium tend to gain less fat than athletes that consume little calcium, **independent of energy intake**. It is so important that your body maintains the calcium concentrations in most tissues so tightly that it will rather cannibalize its own bone tissue to get enough calcium than allow calcium deficiency in any other body part.

How much do you need?

The recommended dietary allowance for calcium is one gram, but during periods of growth this rises to 1.3 grams, so for strength trainees that's an advisable minimum.

The best food sources of calcium include dairy products, especially milk, cheese and yogurt, and selected seafood, such as salmon, sardines (with bones), clams and oysters. Selected vegetables, such as turnips, mustard greens, broccoli, cauliflower and kale also provide relatively large amounts of calcium. Legumes and legume products, especially tofu (soybean curd) and nuts, provide some calcium. Some vegetables such as spinach, rhubarb and Swiss chard may seem decent based on their calcium content, but they're poor sources because of large amounts of oxalic acid, which binds calcium and inhibits its absorption.

Food	Amount	Calcium content
Sardines	3 oz.	400 mg
Milk & yogurt	1 cup	200 - 400 mg
Tofu	½ cup	125 – 227 mg
Cheeses	1 oz.	100 – 200 mg
Beans (kidney, pinto, navy)	1 cup cooked	60 – 120 mg
Almonds	1 oz.	75 mg
Broccoli, cauliflower & kale	½ cup cooked	30 – 80 mg

In practice, to get the maximally beneficial amount of calcium from food, you need to eat dairy, sardines, lots of salmon or a ton of vegetables. In general, it's very difficult to avoid calcium deficiency without consuming dairy [2, 3, 4].

Given this, it's no surprise that dairy-fearing bodybuilders are at serious risk of calcium deficiency [2, 3].

If you choose to supplement calcium, you have to take into account that calcium, magnesium and zinc compete with each other's absorption [2, 3]. So you should take the calcium supplements with meals that are low in these minerals, particularly magnesium given its relatively large intake.

Calcium bioavailability is majorly reduced by several anti-nutrients in plants, such as oxalates, tannins and phytates, whereas it's considerably increased by vitamin D, protein, lactose and phosphopeptides. Calcium absorption is thus typically poor in vegan diets and maximal in the form of dairy. However, any meal that is not vegan normally has a slightly positive effect on calcium absorption due to slowing gastric emptying, giving gastric acid more time to dissolve the calcium, which makes it easier to absorb.

The recommended form of calcium to supplement is calcium citrate. While all calcium salts have similar bioavailability in the range of 23% to 37%, some forms, including the common calcium carbonate, can cause acid rebound, stomach pain and constipation. Calcium citrate is better tolerated by most people.

The Tolerable Upper Intake Level is 2,500 mg, beyond which gastrointestinal side-effects can occur, but given that your body can only absorb ~800 mg of calcium per serving, it makes no sense to consume this much in the first place.

Primary take-home message: To get enough calcium, you practically have to eat dairy or else specific seafood with bones, dairy, tofu or a whole lot of starchy vegetables. If you don't consume dairy or track your calcium intake from the above sources, you should generally supplement calcium citrate.

Magnesium

Magnesium is one of your body's most abundant and important minerals and electrolytes. A healthy body contains 22-24 g of magnesium. The results of insufficient body magnesium include insulin resistance, possible vitamin D deficiency, low testosterone, depression, bone loss, stress hypersensitivity, high blood pressure and disturbed neuromuscular functioning. Magnesium deficiency is also theorized to cause muscle cramps, and one industry-sponsored study found magnesium supplementation can alleviate night cramps, but a 2020 meta-analysis concluded magnesium supplementation is unlikely to reduce most cramps. Magnesium is a micronutrient with significant effects on our gains. Getting enough magnesium can increase testosterone production, strength, lean body mass (trend) and muscular endurance [2, 3, 4], as well as decrease your stress levels and protect against muscle damage. If you're deficient, magnesium supplementation can also improve fat loss.

Magnesium also regulates sleep. While research findings are mixed, there appears to be a relationship between bodily magnesium levels and sleep quality. Anecdotally, many people report deeper sleep in particular when supplementing magnesium with their last meal of the day. Research in healthy, young individuals is scarce, but magnesium supplementation has been found to counteract the loss of exercise tolerance during sleep deprivation, to reduce insomnia and improve sleep quality in the elderly [2] and to improve sleep quality in alcoholics that weren't magnesium-deficient. Magnesium deficiency can impair sleep quality via several mechanisms.

- Magnesium is involved in activating the parasympathetic nervous system to put you in 'rest and digest' mode instead of 'fight of flight' mode.
- Magnesium regulates the secretion of the sleep hormone melatonin.
- Magnesium can bind to gamma-aminobutyric acid (GABA) receptors. GABA is a neurotransmitter that makes you calm.

How much do you need?

The recommended daily intake (RDI) of magnesium is 6 mg/kg per day. Athletes likely need at least 20% more due to the increased need for magnesium during muscle repair and increased magnesium losses via sweat and urine. That means many female strength trainees need over 400 mg per day; men over 600 mg per day.

It's not easy to consume that much magnesium. Many athletes have low magnesium levels, even though they typically eat a lot of magnesium rich starches as part of their high carb diets. Only 15-50% of Americans are estimated to consume enough magnesium.

There is little risk associated with overconsumption, since your body autoregulates its magnesium absorption and excretion. If your magnesium intake is much too high, which in practice requires supplementation, you'll generally notice it, because most people get stomach cramps and diarrhea.

Magnesium is most prevalent in chocolate/cacao, nuts, beans and grains. This is problematic, because legumes, cacao and grains are rich in phytic acid, which inhibits the absorption of magnesium by ~60%.

Moreover, the modern processing and refining of wheat, rice and corn depletes 82-97% of magnesium. Since the agricultural revolution, magnesium has been depleted in the soil and water as well. So if commercially sold starches or legumes are your primary sources of magnesium, you need to consume a lot of them.

Most other whole foods also contain magnesium, but some contain more than others. Green leafy vegetables and seafood rank highly.

Food	Amount	Magnesium content
Spinach	1 cup	150 mg
Halibut	3 oz.	100 mg
Peanut butter	2 tbsp.	50 mg
Beans (kidney, pinto, navy) and blacked-eye peas	½ cup cooked	40 – 50 mg
Brown rice	½ cup	40 mg
Sunflower seeds	¼ cup	40 mg
Chocolate	2 oz.	36 – 51 mg
Whole-grain bread	1 slice	25 mg
Oatmeal	½ cup	25 mg
Milk & yogurt	1 cup	25 – 40 mg

If the grains or legumes have been traditionally prepared (proper soaking/sprouting/fermentation), you can cut their required amounts roughly in half.

Enhancers of absorption	Inhibitors of absorption
Vitamin D	Phytic acid
Protein	Fiber
Carbohydrates	Excessive unabsorbed fatty acids
Fructose	Calcium, iron and zinc (competitive)
Oligosaccharides	

All in all, to consume enough magnesium, your diet needs to be very good, especially during contest prep, or you need to supplement.

If you choose to supplement magnesium, the form is very important. Most magnesium products contain magnesium oxide, which is cheap crap. You absorb virtually none of the magnesium oxide and it can irritate your digestive tract. The popular alternative magnesium (di)glycinate (chelate) is hardly better absorbed than oxide in some human research, so it's also not recommended, though one industry sponsored study found it was equivalent to magnesium citrate. For most guaranteed results, you should supplement magnesium in the form of magnesium citrate or else magnesium chloride, magnesium lactate, magnesium gluconate or magnesium aspartate [3, 4, 5]. Even these best salts are generally only 20-40% bioavailable, which is comparable to the suboptimal food sources of magnesium mentioned above. So even the best supplementation can upset your gut and pose digestive problems, especially in large quantities.

The magnesium supplement should be consumed with a meal, as this enhances bioavailability. However, magnesium supplements should not be taken with meals high in calcium or, to a much lesser extent, zinc, because calcium, magnesium and zinc compete with each other's absorption [2, 3, 4]. Absorption limits are only a considerable concern at dosages of several hundred milligrams normally though, so only calcium is particularly problematic to combine with either zinc or magnesium due to its high relative requirement.

Magnesium oil – magnesium chloride in the form of a lotion/creme that feels like oil but technically isn't – is sometimes marketed as the most bioavailable form of magnesium supplementation. However, there is no published, independent research showing that magnesium has higher bioavailability when applied transdermally compared to oral consumption. In fact, it has never been scientifically demonstrated by anyone other than some shady industry funded pilot studies that magnesium is absorbed through the skin at all. Chemically, hydrated magnesium should be too large to pass through the skin. The best independent research we have is from the Israeli military. They developed a lotion to protect against chemical warfare. Despite being very high in magnesium, the lotion did not affect blood magnesium levels.

Magnesium status is commonly measured with bloodwork, but levels in the blood don't necessarily reflect those in the body, so sufficient levels in the blood are not a guarantee you're not deficient in magnesium. Hair tests are often done to assess magnesium deficiency.

Primary take-home message: It's not easy to consume the optimal amount of magnesium. You need a high dietary fiber intake from minimally processed or traditionally prepared carbohydrate sources or a whole lot of green veggies or seafood. Low carbohydrate diets and most average diets rich in commercially prepared grains are at significant risk of suboptimal intakes.

Phosphorus

Phosphorus is a shockingly unexciting mineral, yet it is important for many things in the body, including bone mineralization, DNA formation, ATP metabolism, cell membrane structure and acid-base balance.

How much do you need?

The RDI is 700 mg per day. Phosphorus is abundant in protein-rich animal foods, so a high protein diet tends to automatically take care of phosphorus requirements. Even vegetarians are not at much of a risk of deficiency, as many grains contain lots of phosphorus and a high vegetable intake can cover your requirements as well. You can even get a lot of phosphorus from soft drinks.

Food	Amount	Phosphorus content
Beans (kidney, pinto, navy)	1 cup cooked	230 – 250 mg
Dairy products	1 serving	200 - 350 mg
Meats, fish, poultry	3 oz.	150 – 250 mg
Peanuts	1 oz.	101 mg
Egg	1	100 mg
Walnuts	1 oz.	98 mg
Soft drinks (Coke)	12 oz.	25 – 40 mg

Primary take-home message: If your diet has any resemblance of healthiness, you don’t need to worry about phosphorus.

Iron

Iron is an essential mineral used in the creation of hemoglobin, found in red blood cells, and myoglobin, found in muscle cells. As you know, blood and muscle are kind of important for trainees. Iron deficiency particularly impairs oxygen transport and thereby your endurance capacity and your resistance to fatigue; it can also impair strength.

Iron is also a co-factor for many enzymes and plays a role in ATP production, amino acid metabolism, niacin synthesis, antioxidant functioning, hormone synthesis, carbohydrate metabolism and DNA synthesis.

How much do you need?

The recommended dietary intake is 11 mg for men and 18 mg for women, rising to a whopping 27 mg when pregnant or lactating and possibly when menstruating. Athletes need up to 50% more, depending on how much they exercise.

Food	Amount	Iron
Beef liver, raw	100 g	4.9 mg
Lamb, 27% fat	100 g	1.8 mg
Beef, 10% fat	100 g	2.2 mg
Egg	1 large	1 mg
Chicken breast, raw	100 g	0.7 mg
Turkey breast, raw	100 g	1.2 mg
Pork loin, 6% fat	100 g	0.8 mg

Almost all whole foods contain small amounts of iron. However, plants are poor sources of iron, because they contain non-heme iron. This is difficult to absorb for the body. To make things worse, many plants contain polyphenols and other phytochemicals that inhibit the absorption of iron. Legumes and grains are worst, because they also contain a lot of phytic acid that binds with the iron to make it unavailable for the human body. Phytic acid can reduce the bioavailability of iron by 2 to 5-fold. Even iron deficient people only absorb 2-3% of the iron in modern grains. Vegetarians are commonly recommended an 80% higher RDI for iron, but given the above data, this may not even be enough for vegans.

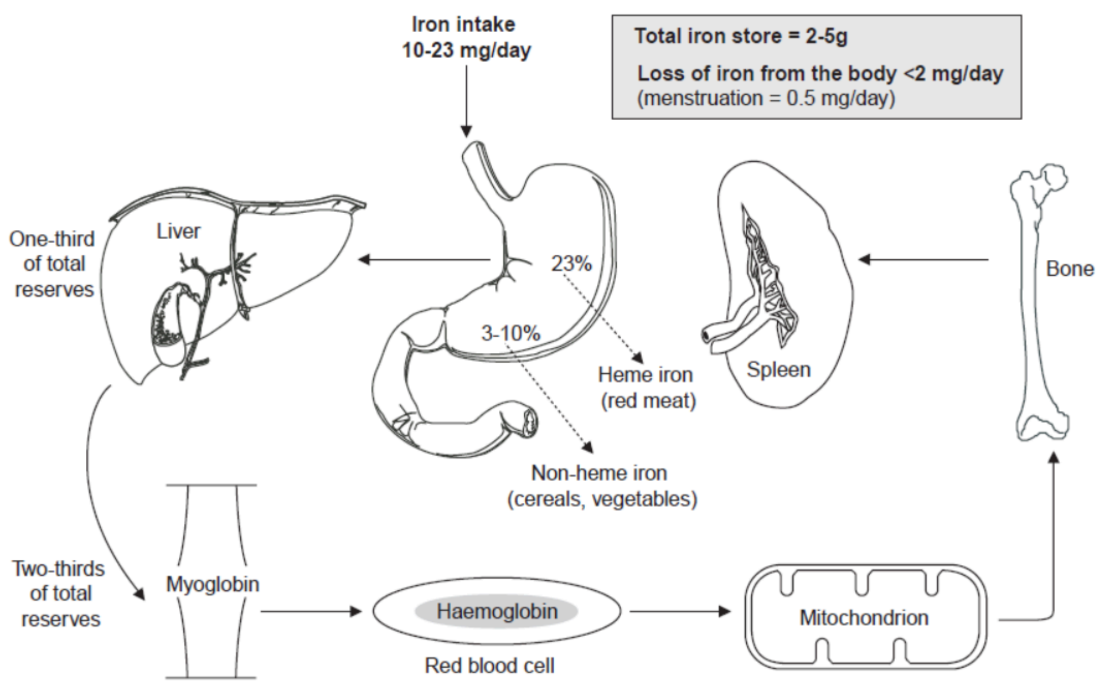


Fig. 1. Body iron stores. ···> indicates 23% of heme iron and 3 to 10% of non-heme iron ingested are absorbed from the gastrointestinal tract.

Source

Animal foods are generally better sources of iron, in particular red meats and organ meats. Liver and kidney from most animals are exceptionally good sources of iron, as well as many other micronutrients. Some types of shellfish are also good sources of iron, but in contrast to is often claimed, many types of clams and oysters mostly contain non-heme iron, so they're surprisingly poor sources of iron [2].

Iron deficiency is one of the most common micronutrient deficiencies in the world. It mostly affects developing countries who can't afford to eat much meat, but athletes are at a high risk because exercise increases iron requirements: 43% of elite male athletes do not consume enough iron. To avoid deficiency without supplementation, endurance athletes practically have to consume animal flesh regularly and possibly even incorporate kidney or liver in their diet 1-3 times per week.

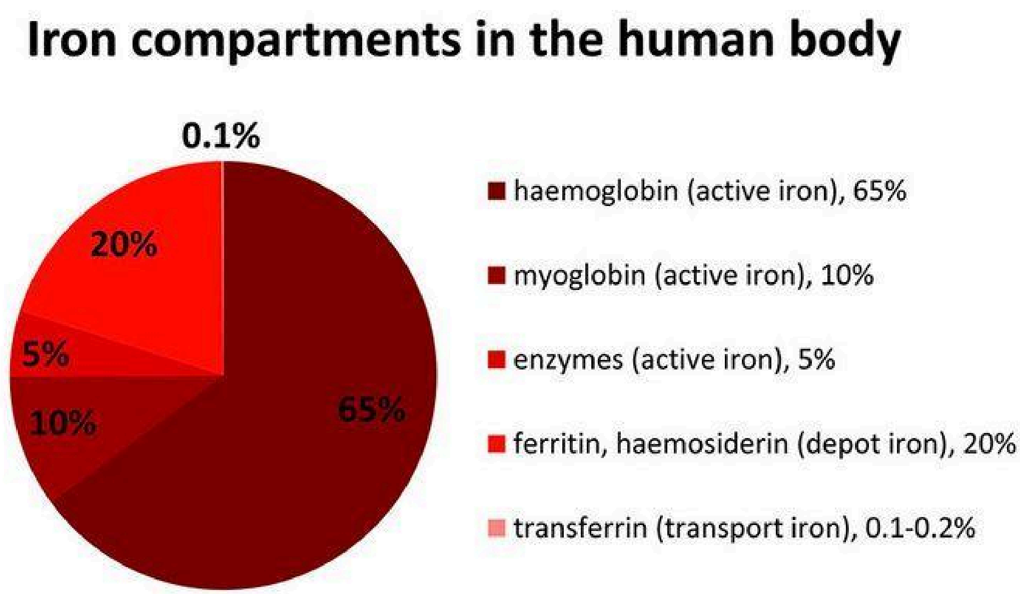
Male, non-vegetarian strength trainees are at considerably lower risk of deficiency in practice, because strength training does not require as much iron as endurance training and because they typically consume relatively large amounts of animal foods. High protein diets centered around animal protein sources generally provide enough iron for male strength trainees that don't do any endurance training or cardio.

Female trainees are at a much higher risk due to the monthly blood loss during menstruation and due to differences in iron metabolism. 52% of female athletes have been found to have iron deficiency, despite already consuming more iron than similar women that don't exercise. Female strength trainees should therefore strongly consider making organ meat, particularly liver and kidney, or seafood a staple in their diet, or at least consume meat or shellfish daily.

Lacto-ovo vegetarians will often have to resort to supplementation or large amounts of eggs. Vegan athletes almost invariably benefit from supplementation.

If you choose to supplement iron, be careful. There is high genetic interindividual variability in iron uptake from the diet and iron toxicity is a serious concern, especially for men. Excessive iron consumption increases your risk of cancer. Many iron supplements irritate the digestive tract. Too much iron consumption can even shorten your life expectancy [2]. The Tolerable Upper Intake Level for iron for adults is 45 mg, although more is commonly taken in the case of iron deficiency.

Plus, once you have saturated your body's iron reserves, everything spills into the blood and the only way to get rid of it then is to get rid of some of your blood, i.e. blood donation.



Source

Bloodwork

Due to the risk of iron toxicity, unless you have good reason to believe you may be deficient, have bloodwork done first to check the indicators of your iron level as per the NIH's National Heart, Lung and Blood Institute's guidelines:

- Serum iron. This test measures the amount of iron in your blood. The level of iron in your blood may be normal even if the total amount of iron in your body is low, so you should also do the following tests.
- Serum ferritin. Ferritin is a protein that helps store iron in your body, so its level tells you how much of your body's stored iron has been used. Low ferritin levels are a clear sign of iron deficiency. High levels do not necessarily mean iron overload, however, as ferritin functions like an acute phase reactant, so inflammation can also elevate it.
- Transferrin. Transferrin is a protein that carries iron in your blood. Transferrin is made by your liver. When body iron stores run low, your liver increases transferrin production to get more iron into your blood. So high transferrin levels are a sign of iron-deficiency anemia. Low levels may indicate liver problems. Closely related tests are total iron-binding capacity (TIBC) and transferrin saturation. Total iron-binding capacity measures how much of the transferrin in your blood isn't carrying iron. Again a high level suggests iron deficiency. Transferrin saturation measures how much transferrin is bound to iron. Here a low level suggests iron deficiency.

Since the direct iron tests are not conclusive, you also want to check for iron deficient anemia by having a full blood count done:
"Often, the first test used to diagnose anemia is a complete blood count (CBC). The CBC measures many parts of your blood.

This test checks your hemoglobin and hematocrit (hee-MAT-oh-crit) levels. Hemoglobin is an iron-rich protein in red blood cells that carries oxygen to the body. Hematocrit is a measure of how much space red blood cells take up in your blood. A low level of hemoglobin or hematocrit is a sign of anemia.

The normal range of these levels varies in certain racial and ethnic populations. Your doctor can explain your test results to you.

The CBC also checks the number of red blood cells, white blood cells, and platelets in your blood. Abnormal results may be a sign of infection, a blood disorder, or another condition.

Finally, the CBC looks at mean corpuscular (kor-PUS-kyu-lar) volume (MCV). MCV is a measure of the average size of your red blood cells. The results may be a clue as to the cause of your anemia. In iron-deficiency anemia, for example, red blood cells usually are smaller than normal."

For more information on the interpretation of your bloodwork, see this article.

If you do decide to supplement iron, ferrous iron salts are better absorbed than ferric iron salts, but other forms of iron, such as heme iron polypeptides, carbonyl iron, iron amino-acid chelates and polysaccharide-iron complexes often result in fewer digestive side effects, so they may be preferable. Iron absorption competes with other minerals like calcium but is enhanced by vitamin C and acidic gut conditions. Food in general reduces iron bioavailability, in contrast to many micronutrients, but taking iron supplements on an empty stomach often leads to stomach pain. It's thus often most practical to consume iron supplements after meals rich in vitamin C and low in calcium. See the table below for an overview of factors affecting iron absorption.

Inhibiting iron absorption	Facilitating iron absorption
• Coffee, tea, milk, cereals, dietary fiber, phosphate-containing carbonated beverages • Multivitamin or dietary supplements containing calcium, zinc, manganese or copper • Antacids, H2 blockers and proton pump inhibitors. • Quinolones and tetracycline antibiotics	• Vitamin C • Acidic foods e.g. tomato sauce • Non enteric coated iron tablets • Fasting ingestion of iron supplements

Source

Primary take-home message: Iron is perhaps the trickiest micronutrient to optimize, because both deficiency and toxicity risk are significant, depending on the population. Men on omnivorous, high-protein diets are typically not at significant risk of deficiency but rather toxicity, whereas female athletes with an intact menstrual cycle should pay careful attention to consuming iron rich foods, notably organ meat or shellfish. Vegetarian athletes likely need to supplement iron. Bloodwork is advisable for everyone in a gray area.

Zinc

Zinc is an essential mineral required for immune functioning, protein synthesis, testicular functioning, testosterone production and wound healing. The diversity of zinc's functions is due to its role in stabilizing enzymes, somewhat like vitamin C. It has more functions than the rest of the trace minerals combined. Since these functions are crucial for exercising individuals, athletes need more zinc than sedentary individuals [2].

The effect of zinc deficiency on our body composition is relatively large compared to other micronutrients. Even marginal zinc deficiency stunts growth and human development and decreases our testosterone levels significantly. Prasad et al. (1996) found that correcting a minor zinc deficiency doubled testosterone levels in healthy, elderly men. Zinc deficiency also directly causes lean body mass losses, which are restored by zinc consumption.

How much do you need?

The current recommended daily intake for zinc is 11 mg for adult men and 8 mg for women (13 mg when pregnant or lactating). However, the current zinc recommendations are based on outdated measurement methodologies that underestimate zinc requirements by nearly 50%. If we then add a ~20% increase in zinc requirements for intensive exercise, the recommended daily intake become 20 mg for men and 14 mg for women.

Zinc only has a few limited storage sites in the body, so you need to consume it regularly, ideally daily.

The following foods are good sources of zinc.

Food	Amount	Zinc content
Oyster	1	12.8 mg
Beef liver	3 oz.	4.3 mg
Crabmeat	3 oz.	3.8 mg
Beef, ground	3 oz.	3.8 mg
Veal	3 oz.	3.5 mg
Chicken (dark meat)	3 oz.	2.4 mg
Shrimp	3 oz.	1.8 mg
Pork	3 oz.	1.8 mg
Legumes	½ cup, cooked	1.0 – 2.7 mg
Nuts	1 oz.	0.9 – 1.5 mg
Rice and pasta	1 cup, cooked	0.7 – 1.2 mg
Egg	1	0.5 mg
Vegetables (average)	1 cup, cooked	0.1 – 0.7 mg

If your diet contains red meat or shellfish on a daily basis, you probably consume enough zinc. 300 g of beef or 500 g of pork or lamb provides ~15 mg of zinc in highly bioavailable form. Crab, organ meats, and lobster are great too. Oysters contain so much zinc you just need to consume one to get your zinc intake for the day. Dark chicken meat is also a decent source of zinc, but chicken breast has only ~1 mg zinc per 100 g.

Without the above foods in your diet, it becomes difficult to consume enough zinc as an athlete. You'd need to consume over a kilo of chicken breast, over 300 g of nuts or over a pound of beans a day. Most starches aren't the best sources of zinc, because the phytic acid in legumes and grains decreases the bioavailability of zinc by ~20%. Unsurprisingly then, global zinc deficiency is estimated to affect 17.3% to 31% [2] of the population and female bodybuilders often don't consume enough zinc either.

Zinc deficiency is probably even more common than we know. The majority of zinc is stored inside cells, so blood work is not very reliable to diagnose zinc deficiency. If your blood work shows you are zinc deficient, you probably are, but even if your blood work comes back ok, you may still be zinc deficient. Common symptoms that you can diagnose yourself include:

- Poor skin quality, including acne and dry, scaling skin (xeroderma).
- Inflammatory or microbial conditions of the mouth, such as white tongue coating or ulcers.
- Poor hair quality, including thinning.

Half-moon shaped and vertical whitening patterns on the nails are often said to be a symptom, but research has not supported this yet.

More clear and severe symptoms include:

- Compromised immune function, including impaired wound healing, frequent illness (including the flu) and inflammatory conditions.
- Diarrhea.
- Loss of appetite and decreased taste and smell.
- Low testosterone and depression.

If you choose to supplement zinc, don't take it with meals rich in dairy or calcium, as high calcium intakes interfere with zinc absorption. Magnesium poses a similar problem, but you typically won't consume enough magnesium from food for it to considerably impair your zinc absorption or vice versa. Most supplemental forms are generally fine, including gluconate, citrate and bis-glycinate, but some people can't absorb zinc oxide well [2, 3].

Beware that more zinc is not always better. The Tolerable Upper Intake Level for zinc has been set at 40 mg daily. Consuming more than this can decrease your 'good' HDL-cholesterol levels and induce copper deficiency, because zinc and copper compete with each other's absorption [2, 3]. Moreover, zinc supplementation can significantly increase your appetite, even if you're not deficient in zinc, which is generally undesirable. While zinc toxicity from food is virtually unheard of, it's not difficult to exceed 40 mg zinc per day with supplements.

Primary take-home message: Optimal zinc intake basically requires daily consumption of dark meats, organ meats or certain kinds of shellfish. If you don't eat those, you should probably supplement zinc, but don't exceed 40 mg per day.

Copper

Another trace mineral that is part of your enzymes, functioning as a co-factor. Copper is also an antioxidant and is involved in ATP production, collagen and elastin cross-linking, blood clotting, immune function and gene expression.

How much do you need?

The RDA for copper is set at 0.9 mg per day. This increases during pregnancy to 1 mg and during lactation to 1.3 mg.

The richest sources of copper are meats (especially organ meats like liver) and shellfish (especially oysters and lobster). Plant food sources rich in copper include nuts (especially cashews), seeds, legumes and dried fruits. Potatoes, whole grains and cocoa are also good sources. In contrast, milk and dairy products are poor sources of the mineral.

Food	Amount	Copper content
Beef liver	3 oz.	12.4 mg
Oyster	3 oz.	6.4 mg
Lobster	3 oz.	1.6 mg
Crabmeat	3 oz.	1.0 mg
Legumes	1 cup, cooked	0.35 - 0.61 mg
Potato	1 baked	0.335 mg
Cocoa powder	1 tbsp.	0.2 mg
Salmon	3 oz.	0.05 mg
Rice and	1 cup,	0.14 – 0.2 mg

pasta	cooked	
Nuts	1 oz.	0.11 – 0.45 mg
Beef, ground	3 oz.	0.07 mg
Pork	3 oz.	0.06 – 0.14 mg
Chicken	3 oz.	0.04 – 0.07 mg
Vegetables	1 cup, cooked	0.02 – 0.06 mg
Milk	1 cup	0.02 – 0.06 mg
Cheeses	1 oz.	0.007 – 0.12 mg
Egg	1	0.007 mg

As you can see, it's not difficult to consume enough copper in a whole foods-based diet. Vegetarians need to pay attention to it though.

Toxicity is rare without supplementation. The Tolerable Upper Intake Level for copper is set at 10 mg per day, although intakes below this level may cause gastrointestinal discomfort in some individuals.

Primary take-home message: Most whole foods-based diets will ensure enough copper intake, though vegetarians may want to check they have enough starches in the diet, as seafood and meat are by far the most abundant dietary sources of copper.

Selenium

We don’t know as much about selenium as we know about most other micronutrients. It’s just a pretty boring trace mineral. We need it though, as it’s again part of enzymatic reactions and plays a role in ATP generation, DNA repair and the immune system.

How much do you need?

The Recommended Dietary Allowance for selenium for adults is 55 µg per day. This increases during pregnancy to 60 µg and during lactation to 70 µg.

Selenium is found in many different whole foods, though its concentration varies greatly in different regions due to changes in the soil. Any remotely healthy whole foods-based diet should result in adequate selenium intake.

Toxicity isn’t a concern without supplementation, though a Tolerable Upper Intake Level has been set at 400 µg per day.

Food	Amount	Selenium content
Fish (e.g. cod or salmon)	3 oz.	30 – 50 µg
Spaghetti or noodles	1 cup, cooked	30 µg
Dairy products	1 cup	< 30 µg
Meats	3 oz.	15 – 40 µg
Egg	1	16 µg
Whole-grain bread	1 slice	11 µg
Brazil nuts	1 nut	10 - 40 µg

Primary take-home message: Any diet based on minimally processed foods should ensure enough selenium intake**.**

Chromium

Another "even researchers don't care" trace mineral. It regulates glucose metabolism and insulin sensitivity, but its role here seems to be non-linear and research on supplementation does not find any consistent benefits for even diabetics.

How much do you need?

The Adequate Intakes (AIs) for chromium for adult men and women up to age 50 are 35 µg and 25 µg, respectively; these values drop to 30 µg and 20 µg for men and women, respectively, over 50 years of age. During pregnancy and lactation, intakes of 30 µg and 45 µg of chromium, respectively, are recommended.

Population	Adequate Intake (mcg)
Men up to 50 years old	35
Women up to 50 years old	25
Pregnant women	30
Lactating women	45
Men over 50 years old	30
Women over 50 years old	20

Many foods, both animals and plants, are rich in chromium, so any whole foods-based diet tends to result in adequate chromium intake. There's practically no toxicity risk.

Food	Amount	Chromium content
Beef	100 g	55 µg
Peanuts	1 oz.	45 µg
Cheese	1 oz.	~ 40 µg
Mushrooms	½ cup raw	29 µg
Green peppers and broccoli	1 cup	5.5 µg
Bananas, and orange and grape juices	1 cup	2 – 7 µg
Apples	1 fruit	1.4 µg
Whole-grain bread	1 slice	1 µg

Primary take-home message: Any diet based on whole foods should ensure enough chromium intake.

Iodine

Iodine is an essential trace element that your body uses to create thyroid hormones, which are key hormones that influence the speed of your metabolism. Iodine is primarily found in seawater and soil nearby the sea. This has become a problem, because modern drink water and salt are so refined that they are now devoid of iodine. Moreover, we have cultivated land in many regions away from the coast. As a result, iodine deficiency and consequently thyroid disease reached epidemic proportions until the Swiss government came up with the nice idea of adding iodine to table salt in 1922. Iodized salt is now publicly available and even mandated by law in some countries. Still, about a third of the global population does not consume enough iodine [2].

Iodine deficiency is commonly diagnosed with a urine iodine test.

How much do you need?

Go to your kitchen and check if your salt is iodized. If not, get some. And check that it actually contains enough iodine. You need at least 150 micrograms (0.15 mg) a day (the RDA) and you definitely shouldn't need more than 10 grams of table salt (NaCl) to reach that. The RDA increases during pregnancy to 220 mcg and during lactation to 290 mcg.

Note that sea salt does not contain sufficient amounts of iodine, in contrast to popular belief. Sea salt generally only contains trace amounts of any kind of mineral. While you may find it more tasty than regular table salt, it is not considerably more nutritious. As such, to obtain enough iodine from salt, the salt needs to be iodized.

If you can't purchase iodized salt or don't consume much salt, here are several good options to consume enough iodine in your diet.

- Eat marine seafood (as opposed to freshwater fish) regularly.
- Consume seaweed once or twice a week. Tip: roll vegetables or glutinous rice in nori (the black sheets of seaweed used in sushi rolls).

- Consume dairy regularly. 6 Large eggs or 2 cups of milk or yogurt provide enough iodine for a day.
- Supplement it. Kelp capsules are the most popular form. The iodine content of seaweed is *extremely* variable though. Just one gram can contain anywhere from 16 to 2,984 micrograms. Overconsumption is rare, as your thyroid autoregulates its production very well. The Japanese routinely eat over 7000 mcg, up to 80.000 in the Northern coastal regions. Dosages of 4.6 *grams* a day have been tolerated safely for years in research. The Asthma Clinic of the Free University of West Berlin has even prescribed 36 *grams* per day without clinical side effects.

Iodine concentrations in food vary enormously per region. In some areas other whole foods may contain enough iodine to get by, but the soil concentration has become so low in modern times that other options than the above may no longer be reliable.

Food	Amount	Iodide content
Kelp	¼ cup	415 µg
Cod	3 oz.	99 µg
Yogurt	1 cup	85 µg
Iodized salt (varies per brand)	¼ tsp. or 1.5 g	70 µg
Milk	1 cup	55 µg
Liver	3 oz.	36 µg
Shrimps	3 oz.	35 µg
Beans (e.g. navy)	½ cup	35 µg
Turkey (white meat)	3 oz.	34 µg
Egg	1	28 µg
White bread	1 slice	23 µg
Cheddar cheese	1 oz.	12 µg

Primary take-home message: Sufficient iodine consumption basically requires consuming significant amounts of dairy or seafood or semi-regular consumption of seaweed. Therefore, using iodized salt is highly recommended to minimize deficiency risk.

Manganese

Manganese, like other trace elements, can function both as an enzyme activator and as a constituent of metalloenzymes. Manganese plays a role in bone, cartilage, and connective tissue synthesis, urea synthesis, carbohydrate/nutrient metabolism, amino acid metabolism, and acts as an antioxidant.

How much do you need?

Population	RDI (mg)
Men	2.3
Women	1.8
Lactating women	2.6
Pregnant women	2

It's easy to consume enough manganese in your diet. Most plants are good sources, so if your diet provides a somewhat healthy amount of vegetables, you should get enough manganese.

Food	Amount	Manganese content
Pineapple	1 cup	2.3 mg
Wheat germ	¼ cup	2.0 mg
Wheat bran–based breakfast cereals	1 cup	1.7 mg
Oatmeal	1 cup	1.3 mg
Blueberries	1 cup	0.9 mg
Leafy green vegetables	½ cup, cooked	0.8 – 1.7 mg
Beans (black, kidney, pinto and navy)	1 cup	0.76 – 0.96 mg
Nuts (almonds, pecans, cashews, hazelnuts)	1 oz.	0.5 – 1.8 mg
Tea	1 cup	0.4 – 1.6 mg

The Tolerable Upper Intake Level for manganese has been set at 11 mg per day. Toxicity is rarely a concern though.

Primary take-home message: Any diet rich in plants, as all healthy diets should be, should ensure sufficient manganese intake.

Molybdenum

Another essential trace mineral that's required for enzymatic processes and functions like an antioxidant.

How much do you need?

The RDA for molybdenum for adults (men and women) is 45 µg per day, with 50 µg suggested during pregnancy and lactation.

Molybdenum is found in many foods and is easy to consume enough of in a whole foods-based diet, but as with many other minerals, the molybdenum content of a given plant food may vary greatly depending upon the concentration of molybdenum in the soil.

Food	Amount	Molybdenum content
Legumes	100 g	184 µg
Meat, fish, and poultry	100 g	~ 129 µg
Grains and grain products	100 g	~ 117 µg
Nuts and vegetables	100 g	< 50 µg
Fruits and dairy products	100 g	< 12 µg

A Tolerable Upper Intake Level for molybdenum has been set at 2 mg, but toxicity is rarely a concern.

Primary take-home message: Any whole foods-based diet should cover molybdenum requirements**.**

Non-essential trace minerals

Fluoride

The major functions of fluoride are related to its effects on bone mineralization and the formation of dental enamels. Fluoride increases the resistance of enamel to acid demineralization and increases tooth mineralization. Read: it's good for your teeth, which is why it's often in your toothpaste and the water supply. It's also in your food, unbeknownst to many people. That's pretty much all you need to know.

Arsenic

While notorious for its toxicity, the small amounts of organic arsenic commonly found in food can have positive effects on DNA methylation and cellular signaling transduction, including that of insulin.

Boron

Boron may be regarded as semi-essential, as its consumption of 1-3 mg per day seems to promote health and reduced inflammation. Boron consumption has beneficial effects on many parts of the body, including our bones, the immune system, the brain and the testes. Boron became popular in bodybuilding circles for a while due to multiple studies showing supplementation increased free testosterone levels in sedentary populations. However, Ferrando & Green (1993) found no effect of boron supplementation on the testosterone levels, strength development or muscle growth of bodybuilders, compared to placebo. A good, high-protein diet probably makes boron supplementation redundant. Boron is abundant in legumes, nuts and avocados, but high-protein animal foods will also get you plenty of boron. Fruits and vegetables in large quantities will also cover your needs.

Food	Amount	Boron content
Raisins, legumes, nuts, and avocados	100 g	1.0 – 4.5 mg
Meat, fish, and dairy products	100 g	~ 0.6 mg
Fruits and vegetables	100 g	0.1 – 0.6 mg

Supplementation will thus probably do more harm than good. A Tolerable Upper Intake Level of 20 mg of boron per day has been established with known toxicity occurring acutely and chronically.

Nickel

Nickel may interact with folate and vitamin B12 in the metabolism of methionine, but you don't need it and toxicity is a concern above intakes of 1 mg per day. Next.

Silicon

Commonly found in the boobs of female physique competitors, it's less known that it's also commonly found in your bones, connective tissues, and cartilage. Silicon is thought to play both metabolic and structural roles. It's also found in many foods, particularly plants, but you don't need it and there doesn't seem to be any practical toxicity risk either, so silicon may actually be more useful in your boobs than your diet.

Vanadium

Vanadium has potent effects in pharmaceuticals, but the threshold dosage required for those effects is much larger than you'll find in food. You don't need it anyway, nor do you need to worry about toxicity. Care-factor: zero.

Cobalt

Cobalt's story is short and sweet: it's part of vitamin B12 (cobalamin). Actually, there's one more tidbit. Cobalt is unique among the elements in that the requirement in humans is not for an ionic form of the metal but for a preformed metallovitamin that cannot be synthesized from dietary metal. Therefore, it is the vitamin B12 content of foods and the diet, rather than the actual cobalt present, that is important in human nutrition. A strong case can thus be made that the care-factor of cobalt is actually minus one.

Micronutrition overview

Vitamins and Minerals	Recommended or Adequate Daily Intake [women / men]	Tolerable Upper Intake Level (per day)	Function
Vitamin A* *Retinol, retinal, retinoic acid* Provitamins *Carotenoids*	700/ 900 µg	3,000 µg (10,000 IU)	Synthesis of rhodopsin and other light receptor pigments; metabolites involved in growth, cell differentiation, bone development, and immune function
Vitamin B1 *Thiamin*	1.1/ 1.2 mg	> 500 mg	Oxidative decarboxylation of α-keto acids and 2-keto sugars
Vitamin B2 *Riboflavin*	1.1/ 1.3 mg	Not established	Electron (hydrogen) transfer reactions
Vitamin B3 *Niacin*	14/ 16 mg	35 mg	Electron (hydrogen) transfer reactions
Vitamin B5 *Pantothenic acid*	5 mg	15-20 g	Acyl transfer reactions
Vitamin B6 *Pyridoxine*	1.3 mg	100 mg	Transamination and decarboxylation

			reactions
Vitamin B7 *Biotin*	30 µg	Not established	CO_2 transfer/ carboxylation reactions
Vitamin B9 *Folate*	400 µg	1 mg (1,000 µg) *for supplements or fortified food*	One-carbon transfer reactions
Vitamin B12 *Cobalamin*	2.4 µg	Not established	Methylation of homocysteine to methionine; conversion of methylmalonyl-CoA to succinyl-CoA
Vitamin C *Ascorbic acid*	75/ 90 mg	2 g (= 2000 mg)	Antioxidant; hydroxylating enzymes involved in synthesis of collagen, carnitine, norepinephrine
Vitamin D* **Provitamins** *Vitamin D2 (ergocalciferol) Vitamin D3 (cholecalciferol)*	15-20 µg	4,000 IU (100 µg)	Regulator of bone mineral metabolism, blood calcium homeostasis, and cell differentiation, proliferation, and growth
Vitamin E* ***Tocopherols Tocotrienols***	15 mg α-tocopherol	1,000 mg of α-tocopherol *(1,500 IU of natural*	Antioxidant

		RRR α-tocopherol or 1100 IU of synthetic all-ractocopherol)	
Vitamin K*	90/ 120 µg	Not established	Activates blood-clotting factors; carboxylates other proteins
* fat-soluble vitamins - all other vitamins are water soluble			
Minerals			
Arsenic	12 - 25 µg	Not established	Methyl group use, signal transduction
Boron	1 -3 mg	20 mg	Bone development, cell membrane stability, immune system function, brain function
Calcium	1,000 mg	2,500 mg	Structural component of bones and teeth; role in cellular processes, muscle contraction, blood clotting, enzyme activation
Chloride	2.3 g	3.6 g	Primary anion;

			maintains pH balance, enzyme activation, component of gastric hydrochloric acid
Chromium	25/35 µg	Not established *supplementation of up to about 1,000 µg of chromium as Cr3+ appears to be safe*	Possibly potentiates insulin signaling
Copper	900 µg	10 mg	Iron use, synthesis of collagen, pigment, neurotransmitter
Fluoride	3 /4 mg	10 mg	Maintenance of teeth and bone structure
Iodine	150 µg	1.100 µg (1.1 mg)	Thyroid hormone synthesis
Iron	8/18 mg	45 mg	O2 transport and use; amino acid metabolism; antioxidant; carnitine, collagen, and thyroid hormone synthesis
Magnesium ***as Mg-citrate, chloride or aspartate, NOT oxide***	310/400 mg	350 mg *from nonfood sources 3-5 g Mg salts cause diarrhea*	Component of bones; role in nerve impulse transmission, protein synthesis; enzyme synthesis; enzyme cofactor

Manganese	1.8/2.3 mg	11 mg	Brain function, collagen, bone, growth, urea synthesis, glucose and lipid metabolism, CNS function
Molybdenum	45 µg	2 mg	Metabolism of nucleotide building blocks, oxidation
Nickel	< 100 µg	1.0 mg	Possibly involved in hormonal membrane or enzyme activity
Phosphorous	700 mg	4 g	Structural component of bone, teeth, cell membranes, phospholipids, nucleic acids, nucleotide coenzymes, ATP- ADP phosphate transferring system in cells, pH regulation
Potassium	4.7 g	Not established	Water, electrolyte, and pH balances; cell membrane transfer
Selenium	55 µg	400 µg	Protection against hydrogen peroxide and free radicals, thyroid

			hormone production
Silicon	10 – 20 mg	1.75 g	Connective tissue, cartilage, and bone formation
Sodium	1.5 g	2.3 g	Water, pH, and electrolyte regulation; nerve transmission, muscle contraction Potassium
Sulphur	Not established		Component of sulfur-containing amino acids, lipoic acid, and two vitamins (thiamin, biotin)
Vanadium	10 µg	1.8 mg	Mimics insulin action, inhibits Na+/K+-ATPase
Zinc	8/11 mg	40 mg	Nutrient metabolism, collagen formation, alcohol detoxification, carbon dioxide elimination, sexual maturation, cell replication and growth

And here's an overview of factors influencing mineral absorption, which may be useful to know in cases of severe deficiency or toxicity.

Mineral	Enhancers of Absorption	Inhibitors of Absorption
Calcium	Vitamin D	Phytic acid Oxalic acid Magnesium Zinc Unabsorbed fatty acids
Phosphorous		large amounts of antacids containing calcium, magnesium, aluminum, or some combination
Magnesium	Vitamin D Protein Carbohydrates Fructose Oligosaccharides	Phytic acid Fiber Excessive unabsorbed fatty acids *Interactions with Calcium, phosphorus, potassium*
Iron (nonheme form)	Sugars (esp. fructose, sorbitol) Acids (like ascorbic, citric, lactic, tartaric) Meat, poultry, and fish Mucin	Polyphenols Oxalic acid Phytic acid Phosvitin Divalent cations such as calcium, zinc, and manganese

Zinc	Ligands or chelators including organic acids (like citric acid and picolinic acid) Prostaglandins Acidic environment	Alkaline environment Phytic acid Oxalic acid Polyphenols Folate (a B Vitamin) Iron Calcium
Copper	Ligands or chelators like amino acids (esp. His, Cys) Organic acids in foods: citric, gluconic, lactic, acetic, and malic acids	Alkaline environment Phytic acid Zinc Molybdenum
Selenium	Vitamins A, C and E	Heavy metals (e.g. mercury) Phytic acid
Chromium	Amino acids: Phe, Met, His Picolinate	Neutral or alkaline environment Phytic acid
Iodine		Goitrogens *Selenium, iron and vitamin A deficiencies may magnify the effects of inadequate iodine*
Manganese	Low-molecular-weight ligands, such as histidine and citrate	Divalent cations Fiber Phytic acid Oxalic acid Iron Copper

How to fill in your micros

Since it's a ton of work to analyze all your food logs and calculate if you're meeting your micronutrient intakes, here's a guide on how to fill your micros that you can use.

➢ Guide

How to fill in your micros