Examine®

Muscle Gain & Exercise Performance Supplement Guide

Table of Contents

Introduction

There's a holy trinity of exercise:

1. Better performance
2. More muscle
3. Less fat

Those are the primary goals of most exercise programs. So why are we covering muscle gain and exercise performance together, separately from fat loss?

Because the latter is merely *associated* with exercise. More precisely, the issue with fat loss is one of fuel: how do you convince your body to burn its precious energy stores? Exercise does help, but not as much, in itself, as a hypocaloric diet (i.e., eating less than you burn).[1]

To lose fat, exercise is a *plus*. To build muscle, exercise is a *necessity*. Any supplement that helps you exercise harder, longer, can also help you build stronger muscles. And since stronger muscles allow you to exercise harder, longer, any supplement that promotes muscle growth can also benefit exercise performance.

Can, but not always *does*. The upper-body muscles of a wrestler would be a literal burden to a marathoner. The kind of exercise you undertake will influence the kind of muscle you grow, and the kind of muscle you grow will make you fitter for some sports than for others.

Even similar sports can lead to very different musculatures. Running marathons is an aerobic activity and builds more "slow twitch" muscle fibers (more endurance than strength). Running sprints is an anaerobic activity and builds more "fast twitch" muscle fibers (more strength than endurance).

> 🔍 ***Digging Deeper:*** **Types of muscle fiber**
>
> Your heart and stomach are muscular organs, but when you think of muscle building, you think of building your *skeletal* muscle — the type of muscle that moves your skeleton. This type of muscle is made of two types of fibers: *type I* (slow-twitch) and *type II* (fast-twitch). Type II fibers are further classified into *type IIa* and *type IIx*, but that's not relevant here.
>
> *Slow-twitch* muscle fibers have more mitochondria, myoglobin, and capillaries, in order to process more oxygen. In other words, they're optimized for aerobic metabolism and thus slow but consistent energy production. They don't fatigue easily, but are relatively weak; they can't support high-intensity efforts (i.e., efforts above the anaerobic threshold). These are the fibers we use for prolonged submaximal exercise activities and postural control.
>
> *Fast-twitch* muscle fibers have less myoglobin and fewer capillaries and mitochondria — they'd rather use the space to store more glucose (as glycogen). They are also larger and more contractile (being larger makes them more contractile, which in turn gives them more growth potential, creating a positive feedback loop). Their being more contractile is part of what makes them ideal for short, powerful bursts of effort. However, their reliance on anaerobic metabolism makes them fatigue quickly. These are the fibers we use for weightlifting or sprints.

Still, the basics of muscle building stay the same, whichever type of exercise you choose to focus on.

1. *Take it slow.* Exercise hard enough to stimulate muscle growth, but not so hard as to injure yourself or impair recovery. Muscle growth takes time and patience; it can only happen so fast.

How fast (or how slow) depends on many factors, starting with genetics. In a 12-week trial, untrained females gained an average of 1.2 kg (2.6 lb) of muscle;[2] in a 10-week trial, males with some lifting experience also gained an average 1.2 kg (2.6 lb) of muscle;[3] in both trials, however, interpersonal variability was very high, so those numbers may not apply to you — don't let them either constrain or daunt you.

2. *Don't give up.* At some point, you'll probably experience a plateau, be it in strength or muscle mass. Few people — few lifters, in particular — deal with plateaus appropriately.

Many people, scared of fat gains, refuse to increase their caloric intake as their muscle mass increases.

Many lifters, scared of muscle loss, refuse to ever reduce their lifting volume or intensity (a deload). Yet muscle and strength are largely maintained even when total lifting volume is reduced by two-thirds,[4] and deloads increase the body's sensitivity to anabolic signals.[5] So, take advantage of those temporary breaks when you seem to hit a wall.

> ⚠ ***Caution:*** **Sometimes, less is more**
>
> Muscle doesn't grow at a linear rate, such as "0.5 kg or 1 lb/month." Everyone has a physiological limit with regard to muscle size, and the closer you get to this limit, the harder it becomes to make any gain. Worse: sometimes your progress suddenly stalls for no apparent reason. It can be tempting then to try out some of the new "breakthrough" supplements that companies produce on a regular basis, but that's seldom the solution. More likely, you need more calories or protein, or you need to alter your workout routine (to stimulate your muscles differently), or maybe you need to exercise *less* for a while, so as to let your body recover.
>
> As surprising as it may sound, exercising *more* is less likely to help. Lifting twice as much, or twice as often, won't double your gains. In fact, according to the vast majority of studies, you won't experience significantly greater gains if you exercise a muscle group more than twice a week.[6]
>
> However, taking a break by exercising less intensely and less often differs greatly from taking a break by spending days glued to your couch, barely moving at all. One study found muscle and strength losses after only five days of disuse (*complete* disuse, mind you, since the entire leg was in a cast).[7]

3. *Don't go crazy with the cardio. Some* cardio can increase blood flow to the muscles, thus speeding nutrient delivery, thus speeding recovery. *Some* cardio can reduce fat gains on a hypercaloric diet by keeping fat-burning pathways active. *Too much* cardio can hinder your progress by burning up calories, cutting into recovery, and interfering with anabolic signaling pathways.[8]

4. *Eat enough, but not too much.* Most people only need a couple hundred Calories per day above maintenance to maximize muscle growth.[9] If you eat too much above maintenance, you risk accumulating too much fat, which you'll later struggle to shed. But if you eat _below _maintenance — if your primary goal is to lose fat — keep in mind that you won't be able to exercise as hard or build as much muscle.

> 💡 ***Tip:*** **Choose a body recomposition strategy**
>
> Bodybuilders aren't typically thought of as brainy, but some among their ranks are experts on the science and practice of fat loss and muscle gain (the two faces of body recomposition). Genetics and even steroids can only take you so far; an effective dietary strategy is what separates the ridiculously ripped and veiny from the average bodybuilder.
>
> You can choose between two "recomp" strategies: *steady* and *cycling*. The former involves eating around your maintenance level of calories to slowly accrue muscle and shed fat. The latter cycles between prolonged bulking (during which large caloric surpluses enable a highly anabolic state) and intense cutting (during which substantial caloric deficits lead to fat being rapidly stripped from the body).
>
> The *steady* strategy is ideal for most people: it is easier to fine-tune, and you'll look good year-round, not just for shows or competitions.
>
> The *cycling* strategy is reserved for competitors and other individuals with significant training and dieting experience. Your ideal caloric surplus — how much you should eat above maintenance in order to maximize muscle gain without accumulating too much fat — depends on many factors: training intensity and frequency, surrounding temperature, genetics, and so forth. If you overbulk, which is all too easy to do, cutting will be hard and take longer, and you'll end losing too much of your hard-won muscle.[10]

5. *Eat meals, don't graze.* Meal frequency is a topic of much debate. For decades, "six meals per day" has been a bodybuilding mantra, but now the intermittent-fasting crowd claims we can be awake for hours, even a whole day, without eating a bite — and be healthier for it!

The truth probably lies somewhere in the middle.

Skeletal muscle protein synthesis changes with amino acid concentrations in the blood; our bodies become desensitized to the anabolic stimulus of protein after about three hours.[11] Eating too frequently can therefore impede muscle protein synthesis.

On the other hand, you don't want to deprive your muscles of the amino acids they need to grow. Since a moderate-sized meal might take up to 5 hours to digest, it seems prudent to eat something every 4–6 hours, which translates to 3–4 meals per day.

6. *Eat enough protein.* Protein is aggressively pushed both on athletes and on the general population, and with good reason: it's essential for many biological functions, including muscle gain or preservation. In this guide, we'll tell you how much you need and when.

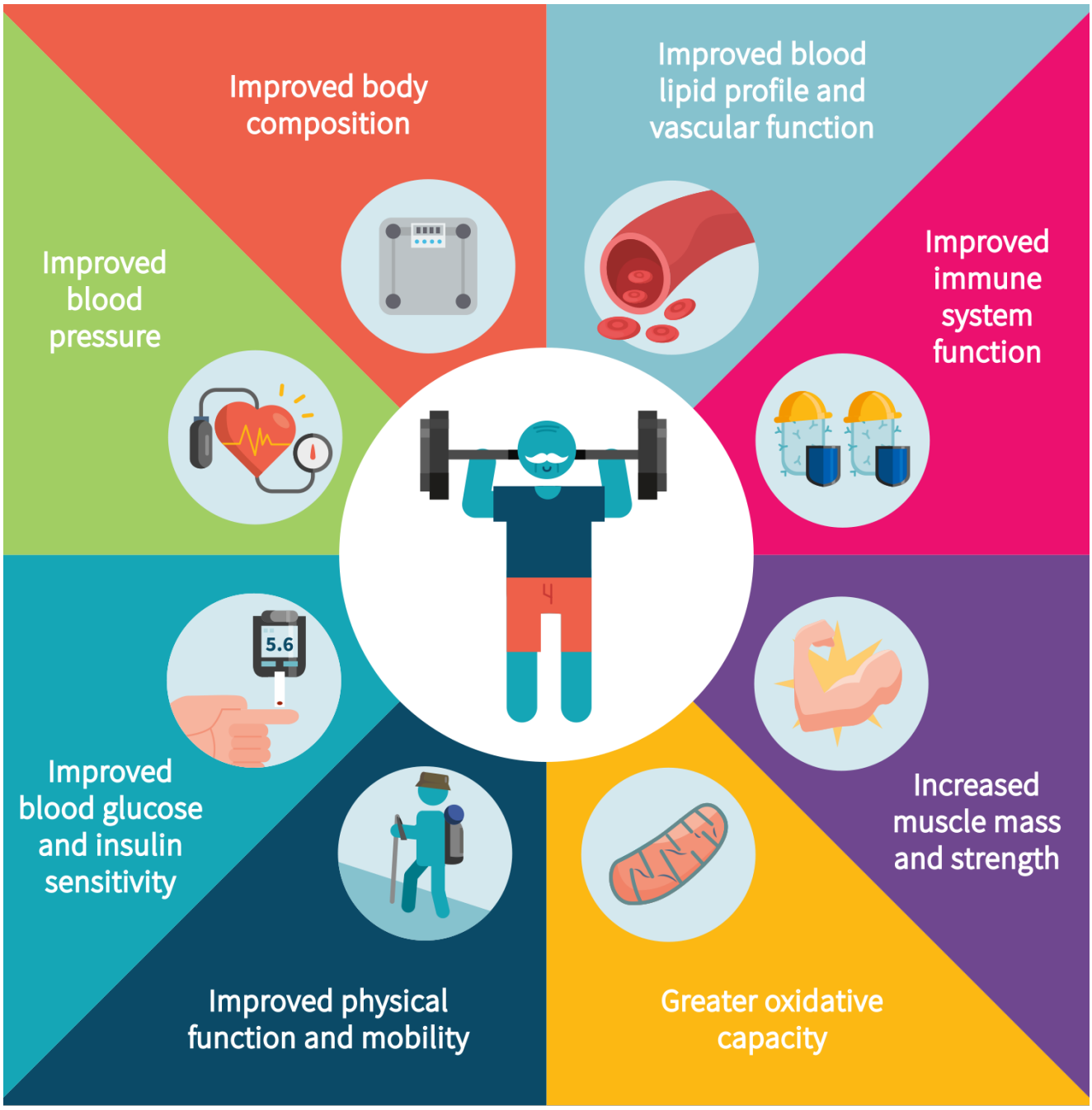
> 💡 ***Tip:*** **Don't assume protein powders are necessary**
>
> Protein powders are used by more than 40% of males who regularly go to the gym, and by more and more people who don't.[12] Remember our advice, though: *eat* enough protein. Not that powders are bad, mind you — except when used to make up for (or even *replace*) a good diet.
>
> Protein-rich foods taste better than protein shakes, and, by affecting gut hormones and through other mechanisms, they're also more filling.[13] So when you think *protein*, think *food* first — not *powder*.

7. *Eat enough fat.* Eating a diet too low in fat (less than 15% of your daily caloric intake) can reduce testosterone levels to the point of impairing muscle gains.[14]
8. *Time your carbs.* You can gain strength and build muscle without much carbs, as shown in ketogenic diet studies involving gymnasts[15] or college-aged weightlifters.[16] But if you do eat carbs, we'll tell you how much you need and when — there are ways to time your carbohydrate intake to maximize exercise performance and recovery.

As you can infer from those eight points, the "food factor" is as crucial to muscle gain as the "exercise factor". Before you turn to supplements to give you an edge, make sure you're eating a healthy, balanced diet, rich in micronutrients. Vitamins and minerals, notably, support many of the functions that promote muscle gain: immune function, hormonal regulation, fuel use, and so on.

As you keep reading this guide and learn about different supplements, remember that the most effective (protein, creatine ...) were originally food components.

The influence of resistance training on chronic disease risk



Adapted from Mcleod et al. *Front Physiol.* 2019.[17]

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Combos

Core Combo

There are four core supplements: creatine monohydrate, dietary nitrates, protein, and carbohydrates.

A couple of hours before exercise, take your dietary nitrates (6.4–12.8 mg per kilogram of body weight, so 2.9–5.8 mg/lb) and 5 g of creatine monohydrate.

Consume protein throughout the day (1.2–2.7 grams per kilogram of body weight, so 0.54–1.23 g/lb), with the help of a protein powder if necessary. Consult the protein entry to set the intake level best suited to your needs.

Consult the Sugars and Other Carbohydrates entry to set your carbohydrate intake.

> 💡 ***Tip:*** **Try one combo alone for a few weeks**
>
> Taking too many supplements at once may prevent you from determining which ones are truly working. Start with just one of the combos suggested here for a couple of weeks before you consider making any modification, such as adding another supplement, altering a supplements dosage, or incorporating the supplements from an additional combo.
>
> When adding another supplement to your regimen, be methodical. For example, you may wish to take all the supplements from two combos. Select the combo that you wish to try first and take this for a couple of weeks. Then, add one supplement from the second combo and wait another week to see how it affects you. Continue this process until you've added all the supplements you wish to.
>
> If a supplement appears in two combos you wish to combine, don't stack the doses; instead, combine the ranges. For instance, if the range is 2–4 mg in one combo and 3–6 mg in the other, your new range becomes 2–6 mg. Always start with the lower end of the range — especially in this case, since the reason why one of the ranges has a lower ceiling in one combo may be due to a synergy with another supplement in the same combo. Reading through the full supplement entry may help you decide which dose to aim for, but if you're not sure, lower is usually safer.

Specialized Combos

For weightlifters (muscle growth and power)

In addition to the core supplements, take caffeine (400–600 mg) with theanine (300 mg) half an hour before an especially strenuous workout, no more than twice a week. After one month, consider adding either alpha-GPC (300–600 mg) or CDP-choline (250–500 mg). Optionally, either of these two cholinergics can be taken every day (still half an hour before exercise).

For athletes who exercise for 1 hour or more (alertness and endurance)

In addition to the core supplements, take BCAAs (10–20 g) before exercise. You can also take β-alanine (5–6.5 g/day), with food. You can also take caffeine (100–200 mg) with an equal dose of theanine half an hour before a bout of _aerobic _exercise.

For people undergoing intense training, such as HIIT

In addition to the core supplements, take β-alanine (5–6.5 g/day) with food and ashwagandha (600 mg of the KSM-66 extract) about one hour before exercise. Soon after exercise, eating or drinking a mix of protein (0.15–0.25 g/kg, so 0.07–0.11 g/lb) and carbohydrate at a CHO:PRO ratio of 3:1 or 4:1 will help replenish glycogen stores and promote muscle recovery.

Other options

If you work out in a fasted state, 20–40 g of protein within the 2 hours following your workout will help preserve muscle mass. If you fail to get enough protein during the day, 3–6.5 g of HMB or 10–20 g of BCAAs can also help you preserve muscle mass.

People with *a lot* of muscle mass can increase the creatine dose from 5 to 10 g.

Should you find it impractical to consume a lot of nitrate-rich vegetables, you could try 6 g of citrulline (or 10 g of citrulline malate) instead. Because glutathione may slow down the rate of nitric oxide breakdown in the bloodstream, adding 200 mg of *N-acetylcysteine* (NAC) to your nitrates or citrulline might prove synergistic.

Adaptogens have not been shown to negatively interact with any compound listed in this guide. They can be added to any combo if mental fatigue is a problem during or after a workout.

Primary Supplements

Creatine

What makes *creatine* a core supplement

Creatine monohydrate is backed by strong evidence for both its safety and its ability to increase power output and anaerobic endurance.

Supplementing with creatine monohydrate increases the body's creatine stores, which are located primarily in the skeletal muscles.[18] Your cells use creatine to regenerate *adenosine triphosphate* (ATP),[18] life's energy currency, before they turn to burning glucose. Creatine can improve muscular strength and control, and thus fitness and mobility.[19] In short, more creatine helps your muscles perform better under pressure (it helps you knock out those last few reps).

Creatine was also investigated for its effects on androgens, with most studies concluding that it had none.[20][21][22][23][24][25][26][27][28][29] Moreover, the increase in testosterone reported is too small to have an effect on muscle gain or exercise performance. A lone study noted a tiny increase in dihydrotestosterone (DHT) with no change in testosterone — a puzzling result that has yet to be replicated.[20]

A summary of creatine-testosterone studies

BETWEEN-GROUP EFFECT	STUDY	SAMPLE SIZE	POPULATION	AVG AGE	DURATION	DOSE	EFFECT ON TESTOSTERONE
Significant	Arazi 2015	20	Active males	20	1 week	20 g/day	↑
	Vatani 2011	20	Trained males	20	6 days	20 g/day	↑
Mixed Results	van der Merwe 2009	20	Male rugby players	18	3 weeks	25 g/day loading 5 g/day maintenance	↑ DHT ↔ Test
No effect	Cook 2011		Male rugby players	20	10 weeks	4.5 g and 9 g	↔
	Cooke 2014	20	Active males	61	12 weeks	20 g/day loading Then 0.1 g/kg 3x/week (avg. 8.8 g/day)	↔
	Crowe 2003	28	Male rugby players	25	6 weeks	3 g/day HMB* + 3 g/day creatine	↔
	Eijnde 2001	11	untrained males	20	8 days	20 g/day	↔
	Faraji 2010	20	Male Sprinters	21	1 week	20 g/day	↔
	Hoffman 2006	33	Male football players	College	10 weeks	10.5 g/day	↔

BETWEEN-GROUP EFFECT	STUDY	SAMPLE SIZE	POPULATION	AVG AGE	DURATION	DOSE	EFFECT ON TESTOSTERONE
	Rhimi 2010	27	Trained males	21	1 week	20 g/day	↔
	Tyka 2015**	19	Male runners	19–30***	6 weeks	0.07 g/kg of lean body mass	↔
	Volek 1997	13	Active males	23	1 week	25 g/day	↔
	Volek 2004	17	Trained males	21	6 weeks	20 g/day loading 4 g/day maintenance	↔

* While there was no creatine-only group, studies have not shown HMB to independently affect testosterone.[30][31][32][33]

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

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

Decades of research have demonstrated that creatine is generally well tolerated. The only recorded adverse effects are nausea, diarrhea, and stomach cramps in people taking more than 10 grams at once, and even at such high doses, these effects are rare.[34] Still, should you find yourself particularly sensitive to creatine's digestive side-effects, split your daily dose, take it with some food, and drink more fluids. You could also try _micronized _creatine monohydrate, which dissolves more easily in liquids.

Creatine can cause water retention, which may notably increase body weight. This effect is largely harmless and is reversed when creatine supplementation is stopped. Theoretically, this water retention could harm people whose kidney disorder is being treated with diuretics,[35] which cause water loss.[34] This possible harm is based on known mechanisms rather than human trial data.

Blood levels of creatin*ine (a byproduct of energy production) are used as an indicator of kidney function, but elevated levels caused by supplemental creatine* are not *a sign that your kidneys underperform.*[36][37] *The current evidence does* not *support the persistent notion that creatine supplementation causes kidney damage. In both long- and short-term studies, daily doses up to 10 grams were found* not *to impair kidney function in people with healthy kidneys.*[34][38][39][40][41][42][43][44] *Daily doses above 10 grams were also found* not *to impair kidney function in people with healthy kidneys, but there are fewer long-term trials on such high doses.[34]

Creatine's ability to raise creatinine levels may, however, mask underlying issues. Consider having your creatinine levels tested (blood and urine tests are available) before you start taking creatine, so as to both get a baseline measurement and check up on your kidney function. If you are already taking creatine yet plan to have your creatinine tested, cease supplementation 3 weeks prior to testing so as to prevent a false positive.

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

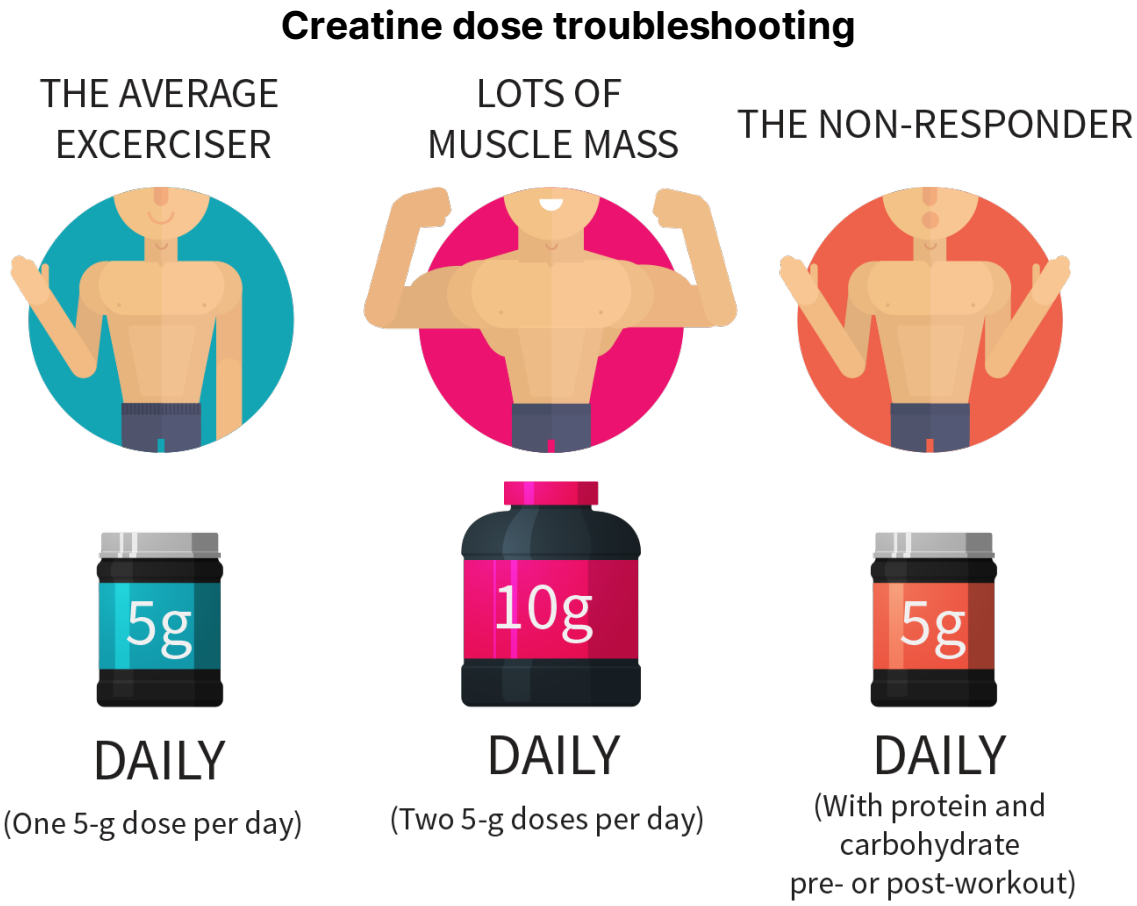
🔍 ***Digging Deeper:*** **ATP and muscular contractions**

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

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

How to take *creatine*

Take 5 grams of *creatine monohydrate* with food (other forms of creatine may be more *expensive*, but studies have not found them to be more *effective*). People with more muscle mass may benefit from as much as 10 g/day, but this claim is not fully supported by the evidence. To supplement with 10 g/day, take 5 grams twice a day.



Loading creatine means taking a high dose for a few days (e.g., 25 g/day for 5 days) before moving down to a smaller maintenance dose, which can be taken indefinitely. This is not necessary for effective supplementation, however; benefits may be felt sooner through loading, but they normalize after a few

weeks.

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

Some people are creatine nonresponders: the creatine they ingest largely fails to reach their muscles.[45][46] Note that even if supplemental creatine fails to enter your muscles it can still benefit you in other ways, such as by improving your body's methylation status (methylation being a way for your cells to help manage gene expression).

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

If you are *not* a creatine nonresponder, you need not worry about supplementation timing, though you should remember that taking your dose with food lowers the risk of an upset stomach.

Creatine can be added to any liquid, but it must be drunk within the day, because creatine in liquids degrades into creatinine over time (the higher the temperature and the lower the pH, the faster the degradation). If you add creatine to a hot liquid, increase your dose a little to compensate for potential degradation.

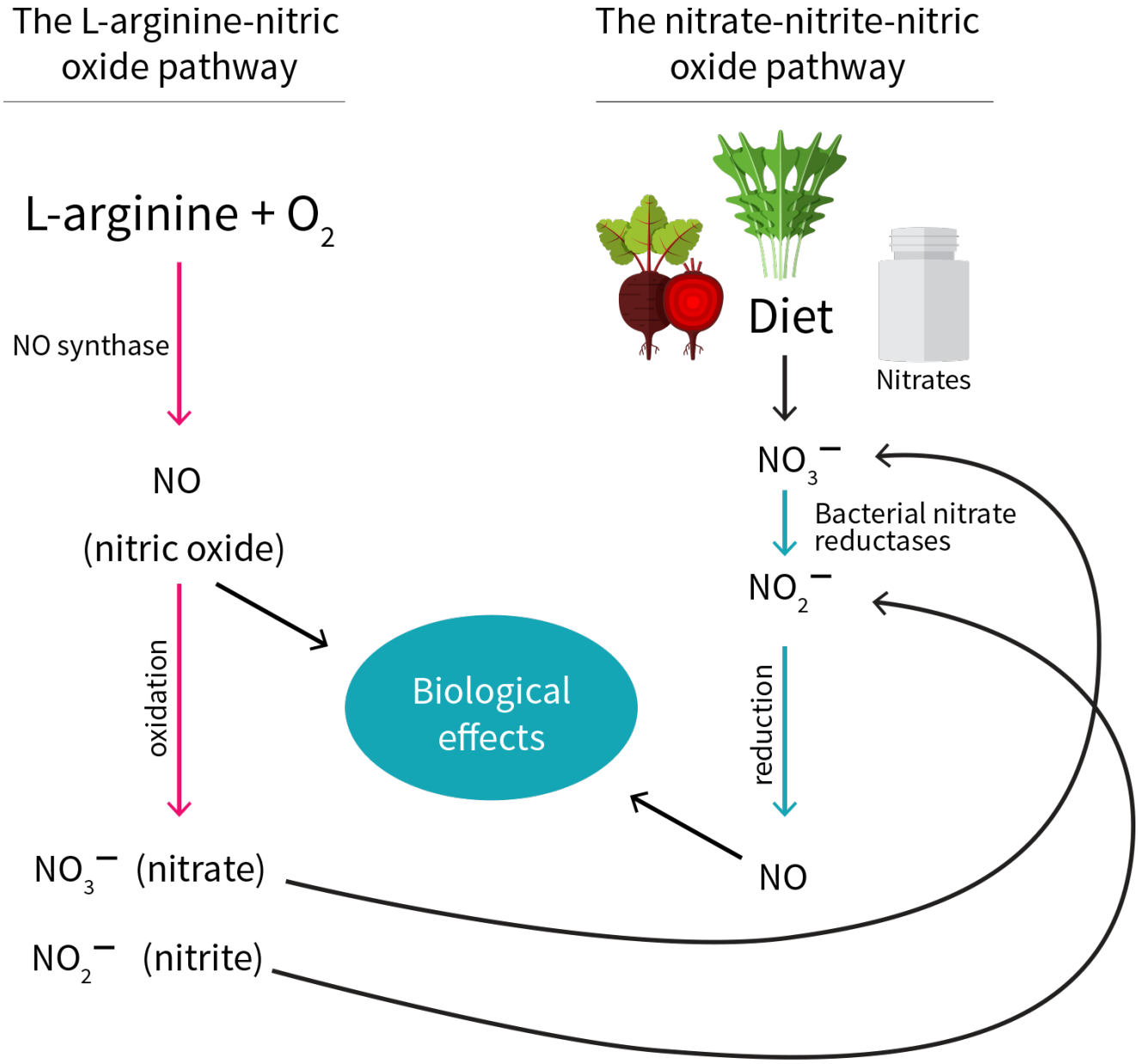
> 💡 ***Tip:*** **Why don't you recommend brands or specific products?**
>
> For two reasons:
>
> - We don't test physical products. What our researchers do — all day, every day — is analyze peer-reviewed studies on supplements and nutrition.
> - We go to great lengths to protect our integrity. As you've probably noticed, we don't sell supplements, or even show ads from supplement companies, even though either option would generate a lot more money than our Supplement Guides ever will — and for a lot less work, too.
>
> If we recommended any brands or specific products, our integrity would be called into question, so … we can't do it. That being said, in the interest of keeping you safe, we drew a short list of steps you should take if a product has caught your interest.

Nitrates

What makes *nitrates* a core supplement

Nitrates can be found in different foods, notably beetroot and leafy green vegetables. Nitrates break down into nitrites, which circulate in the body and are turned into *nitric oxide* (NO) as needed.

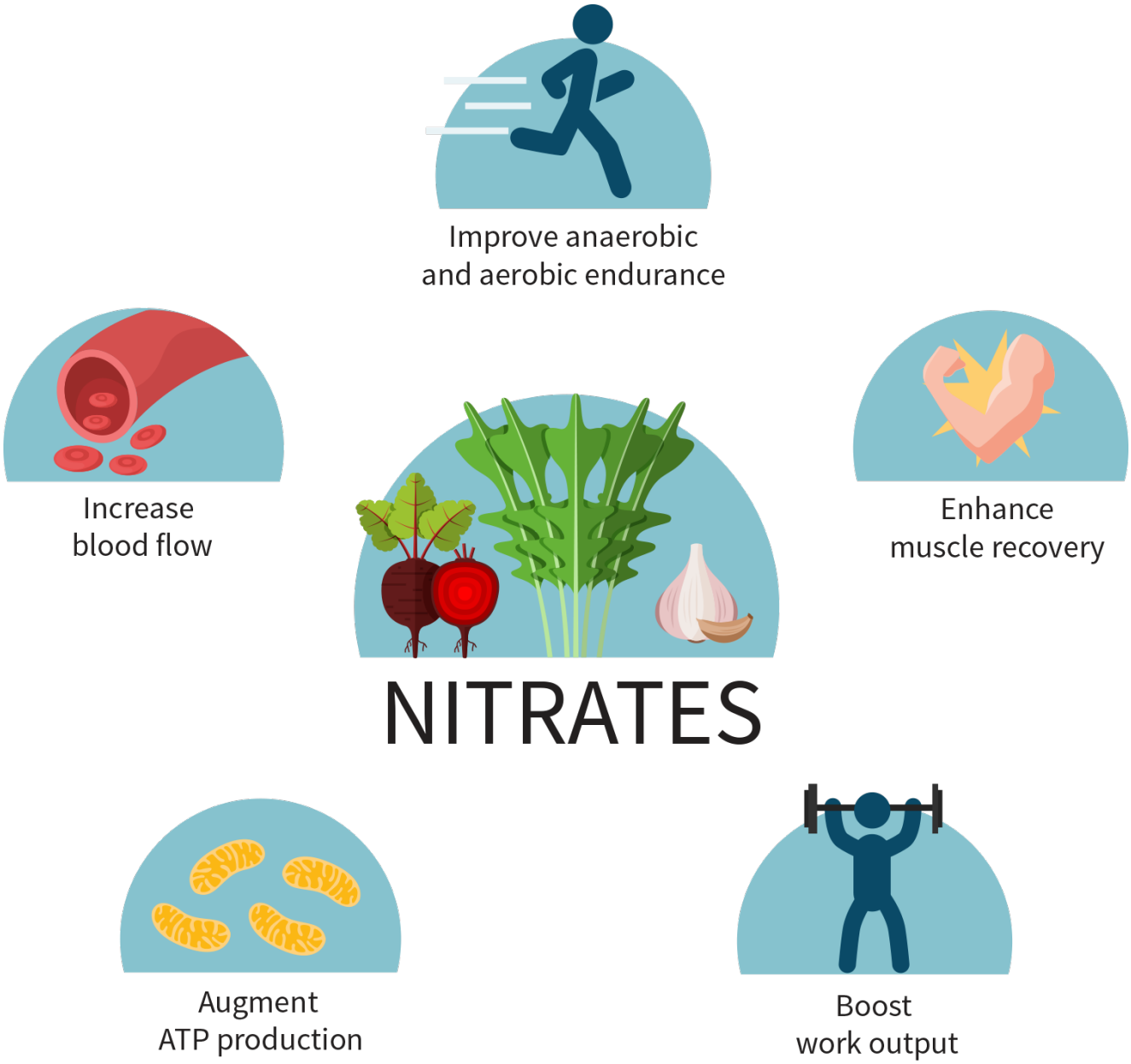
How nitric oxide (NO) is made



Reference: Lundberg et al. *Cardiovasc Res*. 2011.[47]

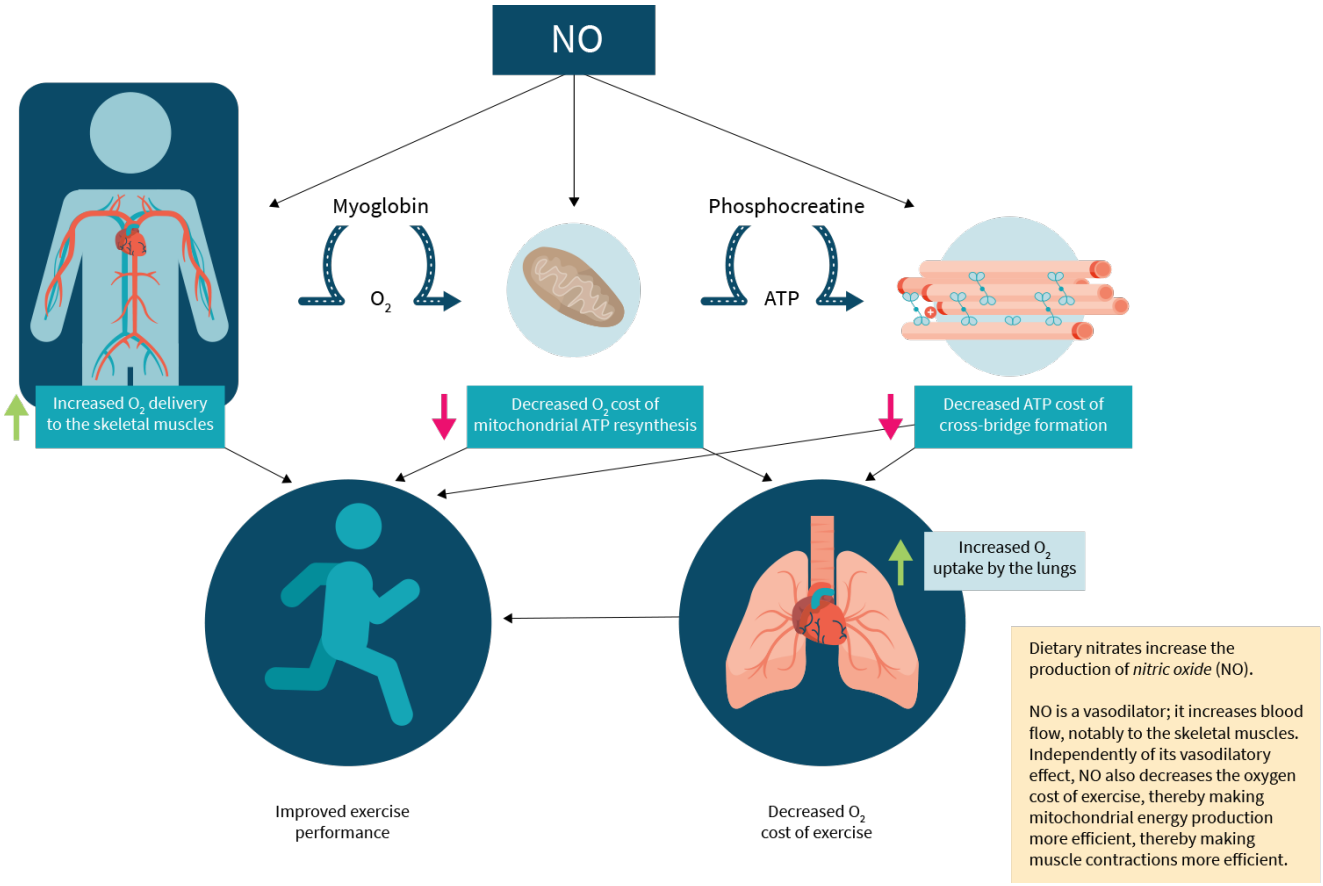
Elevated NO levels during exercise provide a variety of benefits. Nitrate supplementation has been shown to improve aerobic endurance, power output, blood flow, and muscle recovery between bouts of exercise. It may also benefit anaerobic endurance, especially in beginners.

Exercise-related benefits of nitrates



Nitrates improve the body's ability to produce *adenosine triphosphate* (ATP) from food. As we saw, ATP has been called life's energy currency: it powers your cells, including those composing your muscles.

Potential mechanisms for the effects of NO on exercise



Nitrates do not exist as isolated dietary supplements, unfortunately, because of regulations against high quantities of sodium nitrate (a food additive frequently added to meat products). Instead, nitrate supplementation should take the form of a pre-workout meal incorporating leafy greens or beetroot.

Most studies on the performance-enhancing properties of nitrates used beetroot juice. Beetroot powder is also an option (⅛ the weight of raw beetroot), but not in capsules, as you would need to take too many.

Leafy greens are often rich in vitamin K_1, a fat-soluble vitamin that helps with blood clotting and so might decrease the effectiveness of blood thinners, especially anticoagulants (such as warfarin/Coumadin). If you take a blood thinner, you should consult with your physician before consuming a lot of leafy greens.

Due to their goitrogen content, cruciferous vegetables can reduce thyroid hormone production if regularly consumed in high amounts, such as those needed for nitrate supplementation. If you eat a lot of cruciferous vegetables (such as cabbage, collard greens, or kale), make sure to also get enough iodine – through iodine-rich foods (such as cod, shrimp, milk, yogurt, or cottage cheese), iodine-fortified foods (such as iodized salt), or supplements (75–150 mcg/day).

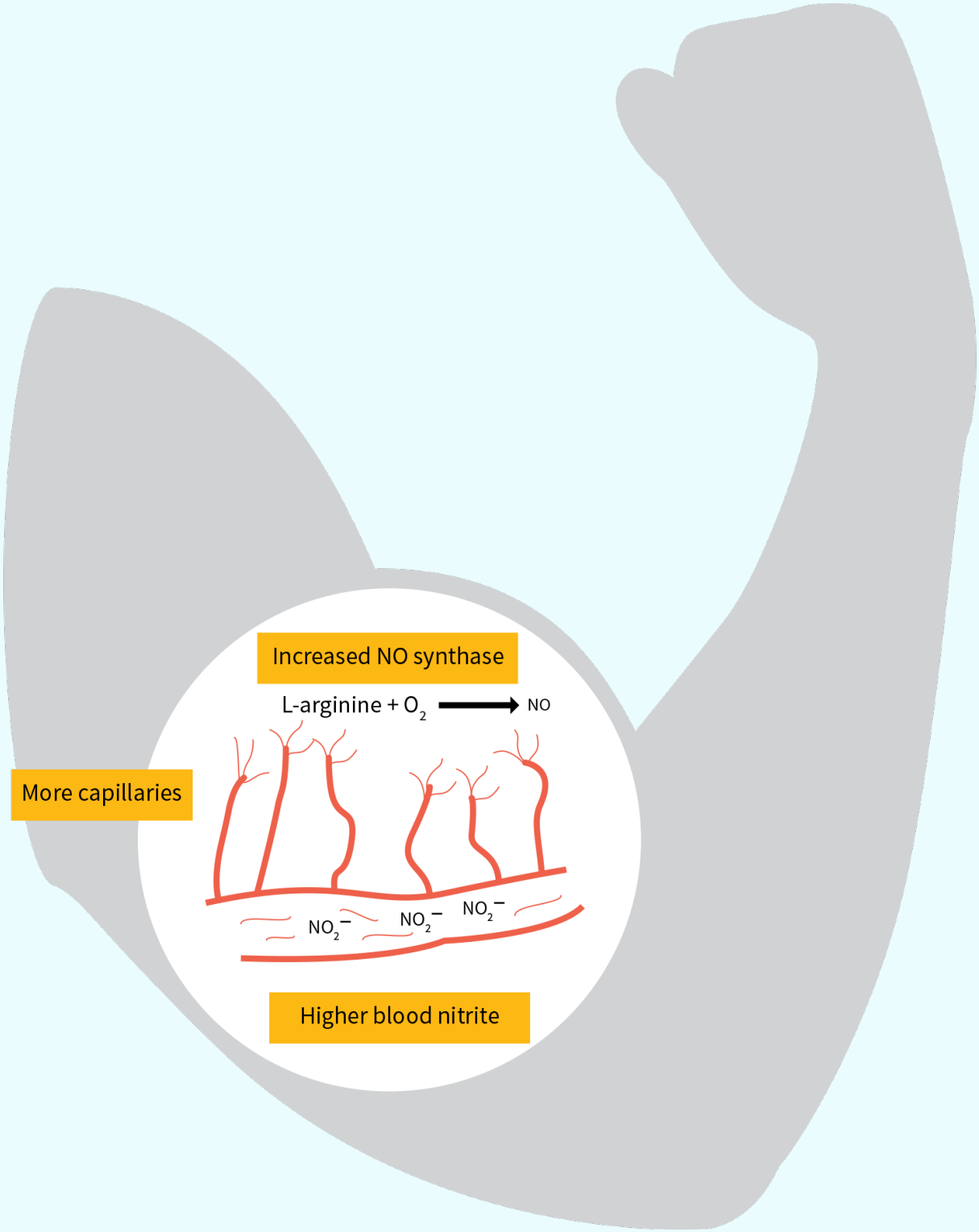
🔍 *Digging Deeper:* How training status interacts with nitrate's effects

From what's known,[48] well-trained people get less benefit from nitrate supplementation, with highly-trained athletes getting little to no performance benefits.[49][50][51] But it's too early to say this with great certainty.

There are several reasons why this could be the case, though, with some shown in the figure below. One reason is that exercise improves the body's ability to make its own nitric oxide through higher plasma nitrite,[52] which is converted to nitric oxide in acidic and low-oxygen conditions, and increased nitric oxide synthase.[53] These two factors could make supplementing it less important.

Athletic muscles also have more capillaries running through them so that they get relatively more blood;[54] thus, there may not be much room for blood flow improvement through nitrate supplementation in well-trained individuals.

Why highly-trained people may not respond to nitrates



Reference: Jones. *Sports Med.* 2014.[55]

How to take *nitrates*

Aim for 6.4–12.8 mg of nitrates per kilogram of body weight (2.9–5.8 mg/lb).

Because the nitrate content of beet-based sports supplements (juice, powder, concentrate) vary so greatly,[56] it's important to check the amount of nitrate the product delivers per serving. Remember to follow these guidelines to find a quality supplement.

Nitrate intake by bodyweight

BODYWEIGHT lb / kg	2.9 (6.4)	3.4 (7.5)	3.9 (8.5)	4.3 (9.5)	4.8 (10.5)	5.2 (11.5)	5.8 (12.8)	mg/lb (mg/kg)
100 / 45	288	338	383	428	473	518	576	mg
125 / 57	365	428	485	542	599	656	730	mg
150 / 68	435	510	578	646	714	782	870	mg
175 / 79	506	593	672	751	830	909	1,011	mg
200 / 91	582	683	774	865	956	1,047	1,165	mg
225 / 102	653	765	867	969	1,071	1,173	1,306	mg
250 / 113	723	848	961	1,074	1,187	1,300	1,446	mg
275 / 125	800	938	1,063	1,188	1,313	1,438	1,600	mg

Nitrate-rich vegetables (mg per 100 g)

NITRATE-RICH VEGETABLES	Nitrates (mg)	Total Oxalate (mg)	Soluble Oxalate (mg)	Vitamin K~1~ (mcg)
Arugula/rocket	362.4	7.1	<0.5	108.6
Turnip greens	346.7	50	—	251
Dill	259	159	60	0
Collard greens	254.5	450	—	437.1
Spinach	248.5	656	542.6	482.9
Swiss chard	236.3	964	207.7	830
Turnips	217.4	210	—	0.1
Rhubarb	199.9	805	223	29.3
Beetroot	199.2	121	74.9	0.2
Celery	196.4	17.5	<0.5	29.3
Mustard greens	187.5	128.7	—	257.5
Radish	177.3	9.2	<0.5	1.3
Lettuce	168.9	13.6	<0.5	126.3
Watercress	164	10	<0.5	250
Bok choy	162	2	—	45.5
Kale	137.5	20	—	704.8
Parsley	130.47	136	76	1,640

This table is composed of averages from multiple samples. Farming techniques, transport, storage conditions, and cooking

methods can all greatly affect the actual nitrate and oxalate content of your food.

References: Jackson et al. *Nutr Res Rev.* 2017[57] ● Lidder and Webb. *Br J Clin Pharmacol.* 2013[58] ● Griesenbeck et al. *Nutr J.* 2009[59] ● Tamme et al. *Food Addit Contam.* 2006[60] ● Siener et al. *Food Chem.* 2006[61] ● Hönow and Hesse. *Food Chem.* 2002[62] ● Santamaria et al. *J. Sci. Food Agric.* 1999[63] ● Dr. Duke's Phytochemical and Ethnobotanical databases ● FoodData Central

Consuming those vegetables in liquid form will increase the rate of nitrate absorption, since solid food particles take longer to digest. Drink your juice, shake, or purée a couple of hours before exercise.

Since the bacteria in saliva play a role in activating dietary nitrates, do not use an antibacterial mouthwash too often, and especially not shortly before consuming nitrate-rich foods. Moreover, the cooking time, if any, should be brief: although cooking reduces the oxalate content more than the nitrate content, the loss of nitrates after fifteen minutes of cooking can still exceed 50%.

Vegetables sorted by nitrate content (mg per 100 g)

NITRATE CONTENT	VEGETABLES
Very high (250+)	Arugula/rocket, collard greens, dill, turnip greens
High (100 to <250)	Beetroot, bok choy, celeriac, celery, kale, kohlrabi, lettuce, mustard greens, parsley, radish, rhubarb, spinach, swiss chard, turnip, watercress
Moderate (50 to <100)	Broccoli, cabbage, cauliflower, endive, savoy cabbage
Low (20 to <50)	Chicory, eggplant, fennel, green beans, green onion, leek, pumpkin/squash
Very low (<20)	Artichoke, asparagus, broad bean, brussels sprouts, carrot, cucumber, dry beans, garlic, lima beans, maize, mushroom, onion, peas, pepper, sweet potato, tomato, white potato

References: Jackson et al. *Nutr Res Rev.* 2017.[57] ● Hord et al. *Am J Clin Nutr.* 2009.[64] ● Jones. *Sports Med.* 2014.[55]

Most vegetables rich in nitrates are also rich in oxalate, which can increase the risk of kidney stones. People already at an increased risk of forming kidney stones, as well as people with oxalosis or hyperoxaluria, should keep their oxalate intake to a minimum.

Other people need not ban all oxalate from their diet, but if you consume high amounts of nitrates (and the dosage range in this guide certainly qualifies) more than twice a week, favor oxalate-poor vegetables. And if you do eat oxalate-rich foods on occasion, consider cooking them and/or pairing them with calcium-rich foods, in order to reduce oxalate absorption.

Vegetables sorted by total oxalate content (mg per 100 g)

OXALATE CONTENT	VEGETABLES
Very high (100+)	Beetroot, collard greens, dill, mustard greens, parsley, rhubarb, spinach, swiss chard, turnips
High (10 to <100)	Cauliflower, celery, kale, lettuce, turnip greens
Moderate (2 to <10)	Arugula/rocket, asparagus, carrot, radish, sweet potato, watercress
Low (<2)	Bok choy, cabbage, radicchio

Because glutathione may slow down the rate of NO breakdown in the bloodstream, adding 200 mg of *N*-

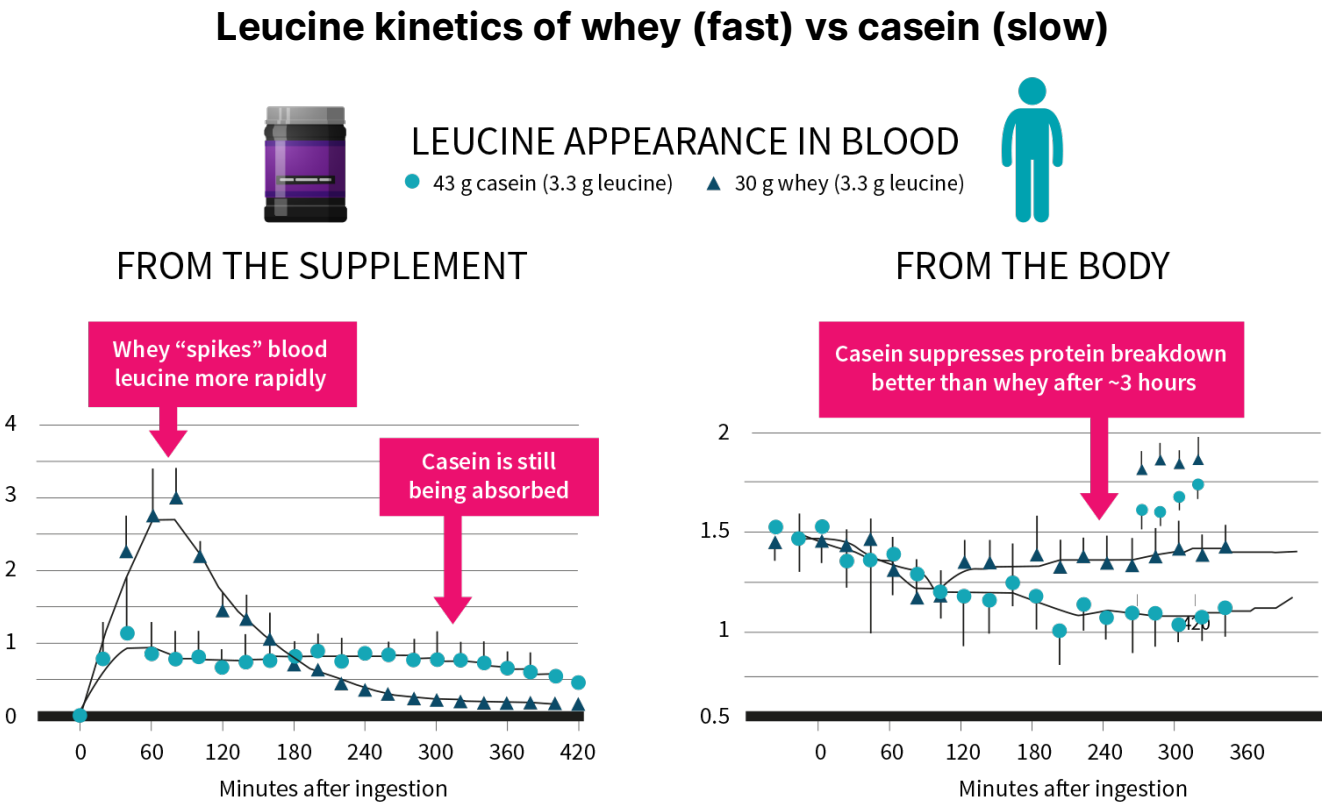
acetylcysteine (NAC) to your nitrates might prove synergistic.

Protein

What makes *protein* a core supplement

Any protein found in food or supplements is called dietary protein. The protein you ingest is digested into amino acids, which are then recombined as muscle fibers, among other things. Some amino acids (chiefly leucine) are especially important for muscle growth. To maximize muscle growth and exercise performance, you need to consume enough protein.

Whey protein and casein powders are both derived from milk protein (which is 20% whey and 80% casein). Whey protein digests quickly, whereas micellar casein digests slowly, so a case could be made for drinking the former around your workout (to quickly feed your muscles) and the latter before bed (to keep your muscles fed overnight), though recent evidence suggests that bedtime protein may not provide any additional benefit if enough protein is consumed during the day.[65] If you'd rather buy only one type of protein powder, milk protein isolates are available, but a whey protein concentrate that is at least 80% protein will be much cheaper and the best bang for your buck.



Adapted from Boirie et al. *Proc Natl Acad Sci USA*. 1997.[66]

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

Overall, whole foods are the healthier choice, but if your food intake does not cover your daily protein

needs, you could add a supplement (preferably a powder, since the protein-to-calorie ratio of powders tends to be higher than that of other protein supplements, such as protein bars).

How to take *protein*

In the United States, the Recommended Dietary Allowance (RDA) of 0.8 grams per kilogram of body weight (0.36 g/lb) is considered the minimum amount of protein a healthy adult must consume daily to prevent muscle wasting when total caloric intake is sufficient.[67]

The current evidence suggests, however, that this amount has been underestimated. Recent studies point to 1.0–1.2 g/kg as the minimum daily intake before the body starts downregulating important non-essential processes, from immune function to muscle protein synthesis.[68][69][70] Even a reanalysis of the data used to establish the above RDA suggests the minimum daily intake should be at least 1.0 g/kg.[71]

So, how much protein do _you _need daily? Here's a quick rundown of how much protein you may need in different situations. If you want to know more, check out our in-depth article on protein needs.

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

Daily protein intake

BODY WEIGHT	BODY WEIGHT	0.36	0.45	0.54	0.68	0.77	0.91	1.00	g/lb
LBS	KGS	0.8	1.0	1.2	1.5	1.7	2.0	2.2	g/kg
100	45	36	45	54	68	77	91	100	g
125	57	45	57	68	85	96	113	125	g
150	68	54	68	82	102	116	136	150	g
175	79	64	79	95	119	135	159	175	g
200	91	73	91	109	136	154	181	200	g
225	102	82	102	122	153	173	204	225	g
250	113	91	113	136	170	193	227	250	g

BODY WEIGHT	BODY WEIGHT	0.36	0.45	0.54	0.68	0.77	0.91	1.00	g/lb
LBS	KGS	0.8	1.0	1.2	1.5	1.7	2.0	2.2	g/kg
275	125	100	125	150	187	212	249	275	g

References: Schoenfeld and Aragon. *J Int Soc Sports Nutr*. 2018.[72] ● Jäger et al. *J Int Soc Sports Nutr*. 2017.[73] ● Thomas et al. *Med Sci Sports Exerc*. 2016.[74] ● Institute of Medicine. Protein and Amino Acids (chapter 10 in *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids*. The National Academies Press. 2005. DOI:10.17226/10490)

Unless you have a pre-existing condition that affects your liver or kidneys, the intakes in the above table will not harm these organs.[75]

For maximal muscle protein synthesis (MPS) stimulation, the minimal per-meal dose of quality protein (such as can be found in meat, eggs, dairy products, and soy) is 0.24–0.40 g/kg for adults in their twenties[76][77] and 0.40–0.60 g/kg for adults aged sixty and older.[76] Spreading your protein intake over a few meals, making sure this 0.40–0.60 g/kg threshold is met with each meal, will generally result in greater lean mass and strength.

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

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

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

* The ranges in this table represent individual variations. The minimum protein requirements increase as you age, but to what degree is uncertain because of the age gap left by the studies: most subjects were in their 20s (0.24–0.40 g/kg) or 60s/70s (0.40–0.60 g/kg). For people in their 30s, 40s, or 50s, the 0.29–0.53 g/kg range reflected in this table is an educated guess.
References: Schoenfeld and Aragon. *J Int Soc Sports Nutr*. 2018.[72] ● Rafii et al. *J Nutr*. 2016.[69] ● Morton et al. *Front Physiol*. 2015.[77] ● Moore et al. *J Gerontol A Biol Sci Med Sci*. 2015.[76] ● Rafii et al. *J Nutr*. 2015.[68]

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

After exercising, when your muscles are more sensitive to the anabolic effect of protein, take a dose in the

range of your "desirable minimal protein intake per meal" (as shown in the table above). If you've been exercising on an empty stomach, you'll be in negative protein balance, so take this dose as soon as possible. Otherwise, try to take it within a couple of hours — the exact size of your "window of opportunity" depends on how much protein you're still digesting.[78]

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

Sugars and Other Carbohydrates

What makes *sugars and other carbohydrates* a core supplement

Sugars are quickly digested carbohydrates. In addition to providing your muscles with readily usable energy, they cause a sharp rise in insulin, which improves blood flow and the effects of nitric oxide — two benefits that contribute to peak physical performance.

Sugars are especially beneficial to anaerobic exercise, such as weightlifting or sprints, but they can also fuel the longer endurance events, such as marathons. Workouts of mild intensity and duration, however, can simply be fueled by other carbohydrates consumed throughout the day.

How to take *sugars and other carbohydrates*

You can use the chart below to help set your total daily carbohydrate intake (in grams) according to your body weight (in kilograms or in pounds). If you have a BMI of more than 25, you may want to calculate your carbohydrate requirements based on your goal body weight rather than your current body weight, so as to avoid overeating.

Daily carbohydrate intake

INTENSITY	ACTIVITY	g/kg	g/lb
Low	Skill-based or general activities	3–5	1.4–2.3
Moderate	Exercise program (1 hr)	5–7	2.3–3.2

INTENSITY	ACTIVITY	g/kg	g/lb
High	Endurance program (1–3 hr)	6–10	2.7–4.5
Very high	Extreme commitment (4–5+ hr)	8–12+	3.6–5.4+
Strength athletes	Resistance training (weightlifting, bodybuilding, etc.)	4–7	1.8–3.2

Adapted from Thomas et al. *J Acad Nutr Diet.* 2016.[79]

Athletes can use the table below to optimize the timing of their carbohydrate intake. Other people can just remember the following sugar protocol: If you exercise for 45 minutes to 2 hours, aim for 30–60 g/hr; if you exercise longer, aim for 60–90 g/hr.

Carbohydrate intake timing

	SITUATION	TIME	CARBOHYDRATES
Before	Loading	36–48 hr before the event	4.5–5.4 g/lb/day (10–12 g/kg/day)
	Pre-event	1–4 hr before the event	0.5–1.8 g/lb (1–4 g/kg)
During	Brief exercise	≤45 min	Unnecessary
	Sustained high-intensity exercise	45–75 min	Sugars: ≤30 g/hr
	Endurance exercise, including stop-and-start sports such as basketball, soccer, etc.	60–150 min	Sugars: 30–60 g/hr
	Ultra-endurance exercise	>150 min	Sugars: ≤90 g/hr
After	Speedy refueling	≤10 hr between two fuel-demanding sessions	0.5 g/lb/hr (1.0–1.2 g/kg/hr) for the first 4 hours then resume normal intake
	Typical refueling	>10 hr between two fuel-demanding sessions	0.5–0.7 g/lb (1.0–1.5 g/kg) over the first 30 minutes then resume normal intake

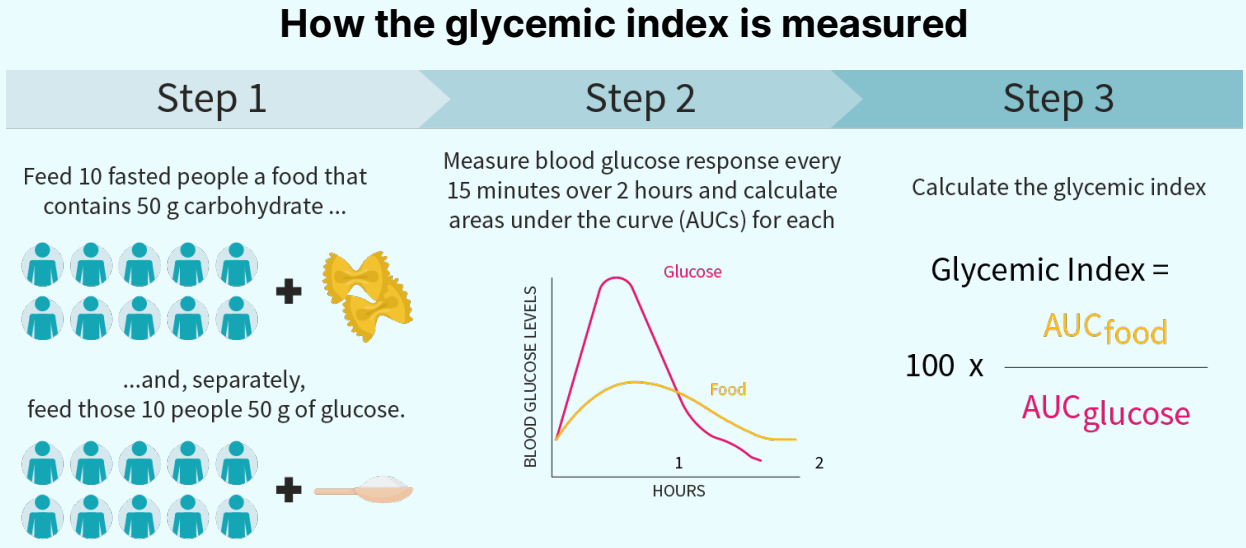
Adapted from Thomas et al. *J Acad Nutr Diet.* 2016.[79]

Athletes should be careful not to overdo their sugar consumption before a game or competition. Too much at once may cause temporary reactive hypoglycemia, a short period of low blood sugar, which could hurt sports performance. If this is something you regularly experience, switching to a pre-game carb source with a low *glycemic index* (GI) may provide you with a more even source of energy.

🔍 ***Digging Deeper:*** **Glycemic index vs. glycemic load**

The glycemic index was developed back in the 1980s and was used to rank carbohydrates on a scale of 0 to 100 based on their ability to raise blood sugar after consumption.[80] To determine ranking, fasted participants would come in and be fed a serving of food containing 50 grams of carbohydrates. The greater and more prolonged the response, the higher the GI rating. A high GI food is typically characterized by rapid digestion and absorption into the bloodstream. High GI foods are greater than 70, moderate is 56 to 70, and low GI is less than or equal to 55.

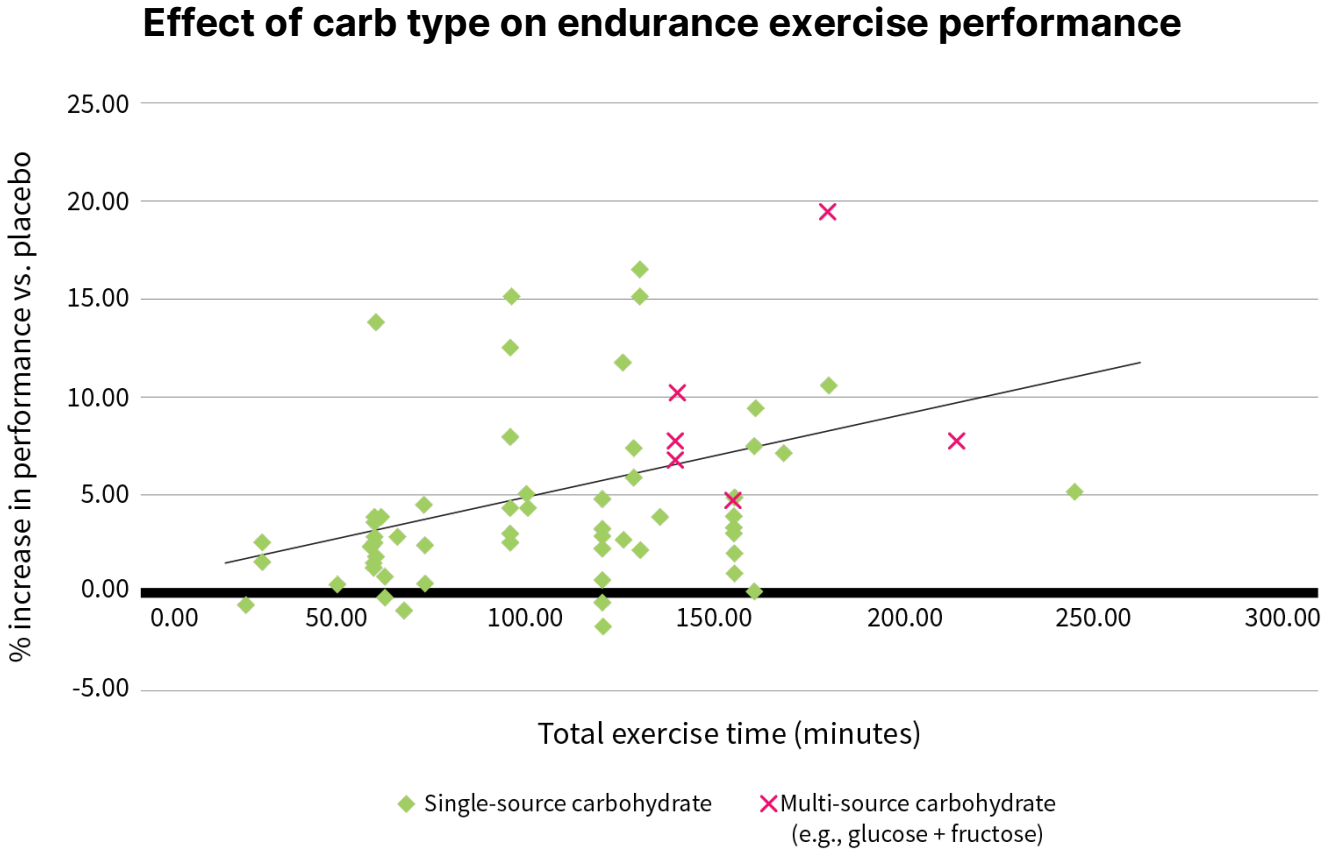
However, this model does not take into account the quantity of food consumed in a real life, free-living setting. The use of the glycemic load (GL) was meant to correct that problem. To calculate the glycemic load of a food, you need both the glycemic index rating of your food and how much you are consuming. So, GL = (Glycemic index rating * grams of food consumed) / 100. High GL foods are greater than 20, moderate is 11 to 19, and low is 1 to 10. Some foods, like watermelon, can have a very high GI (72). Once serving size is taken into account, their GL can be very low, in this case a GL of 4 for watermelon. A table of calculated GIs and GLs can be found here.[81]



As a general rule, eating a high-carb meal before exercise decreases the need for a sugary drink during exercise. Conversely, the less carbohydrate in your regular diet, the greater the performance-enhancing effects of a sugary drink during exercise.

During exercise, drinking a mix of two or more sugars or other simple carbohydrates (glucose, fructose, maltose, etc.) may help increase the rate at which they are absorbed and oxidized for energy. Although maltodextrin is not a simple sugar, its absorption rate is similar to that of dextrose (D-glucose), so it can be used as part of your mix.

Your exercise beverage should be 6–8% carbohydrate (a lot less than most sports drinks) to optimize absorption and oxidation and minimize the risk of an upset stomach. Also to avoid stomach discomfort, no more than half your mix should be fructose, and you should steer clear from sodas, since their carbonation and acidity can cause gastrointestinal upset during exercise.

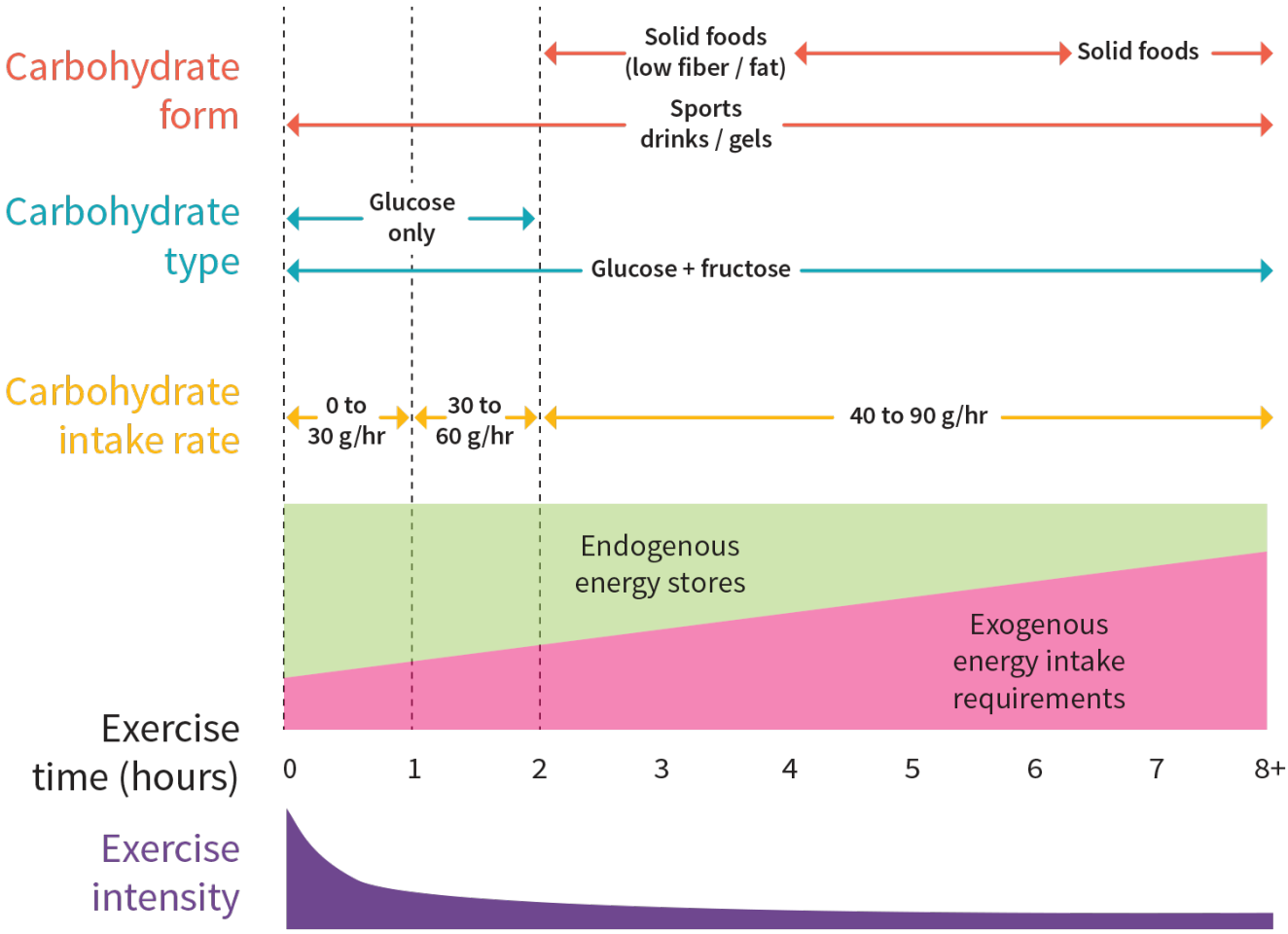


Adapted from Stellingwerff and Cox. *Appl Physiol Nutr Metab.* 2014.[82]

The main factors to influence muscle glycogen resynthesis are: carbohydrate type, ingestion rate, intake timing, coingestion of carbohydrate and protein, and caffeine intake. Ingesting a high-GI food or beverage at a rate of 1.0–1.2 g/kg/hr (0.5 g/lb/hr) for the first 4 hours following exercise will help maximize the speed of glycogen resynthesis. Adding protein (at a CHO:PRO ratio of 3:1 or 4:1) and/or caffeine may slightly increase the speed of glycogen resynthesis, too.

The speed of glycogen resynthesis matters mostly for people who exercise more than once a day. As a rule, carbohydrate supplementation during and after exercise is more of a concern for endurance athletes than for strength athletes; the latter should focus on consuming adequate carbohydrate throughout the day and before exercise. For both types of athlete, the shorter the rest between workouts, the more important intake timing becomes.

Summary recommendations for carb intake during endurance exercise



Adapted from Stellingwerff and Cox. *Appl Physiol Nutr Metab.* 2014.[82]

Secondary Supplements

Beta-Alanine

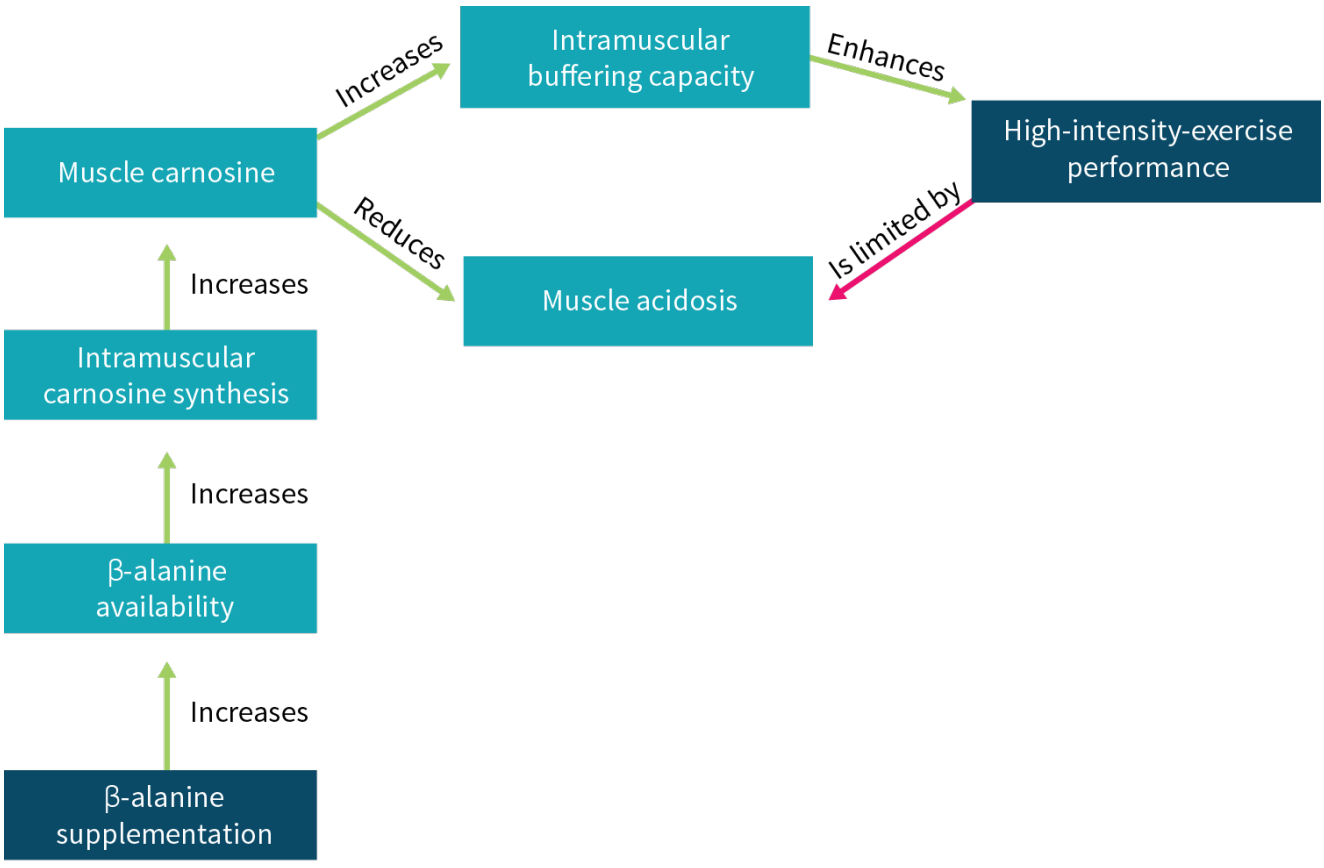
What makes *beta-alanine* a primary option

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

β-alanine is one of the most heavily studied *ergogenic aids* (i.e., performance-enhancing supplements), and the results are consistent. Chronic supplementation — taking β-alanine consistently for several weeks — increases endurance exercise performance during bouts of exercise lasting 1–10 minutes, regardless of fitness level or type of exercise.[83] Since the greatest benefit is for bouts of 1–3 minutes (with daily doses of 2.4–6.4 grams),[84] β-alanine should be an ideal supplement for combat-sport athletes such as boxers.[85]

Even the greatest benefit isn't large, mind you: a performance increase of some 2–3% on average. For most recreational athletes, such a minute advantage has little to no value. For competitors, though, it can make the difference between first and second place — or victory and defeat, in a boxing match.

Effects of β-alanine on high-intensity-exercise performance



Reference: Artioli et al. *Med Sci Sports Exerc.* 2010.[86]

But there's a catch. β-alanine only helps with intense exercise, in which lactic acid kicks in after about a minute. Imagine running a fast lap around the track or doing a volume set of squats that feels like the longest sixty seconds of your life. β-alanine supplementation will mostly benefit athletes who exercise hard in the 1–4-minute range.

If your goal isn't to compete but to gain muscle or lose fat, however, you may want to spend your money on creatine and whey protein (and the _Fitness Guide_) rather than β-alanine, whose supplementation was shown to have no effect on body composition in collegiate football players and wrestlers,[87] untrained men beginning a resistance-training program,[88] and recreationally active females.[89]

How to take *beta-alanine*

Take 3–6.5 g/day. It may take up to 4 weeks before the full effects are felt.

If you have a long workout planned, aim for the higher end of that range. It is better to take this supplement even on rest days, but skipping one or two days a week is not a major issue. While beta-alanine can be taken at any time of the day, it may be better absorbed with a meal.

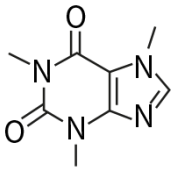
A common side-effect of beta-alanine is paresthesia (a tingling sensation, as when your leg "falls asleep"). Taking smaller doses throughout the day or using time-release formulations can help reduce the prickling sensation on the skin (especially the face). Paresthesia is harmless, if unpleasant.

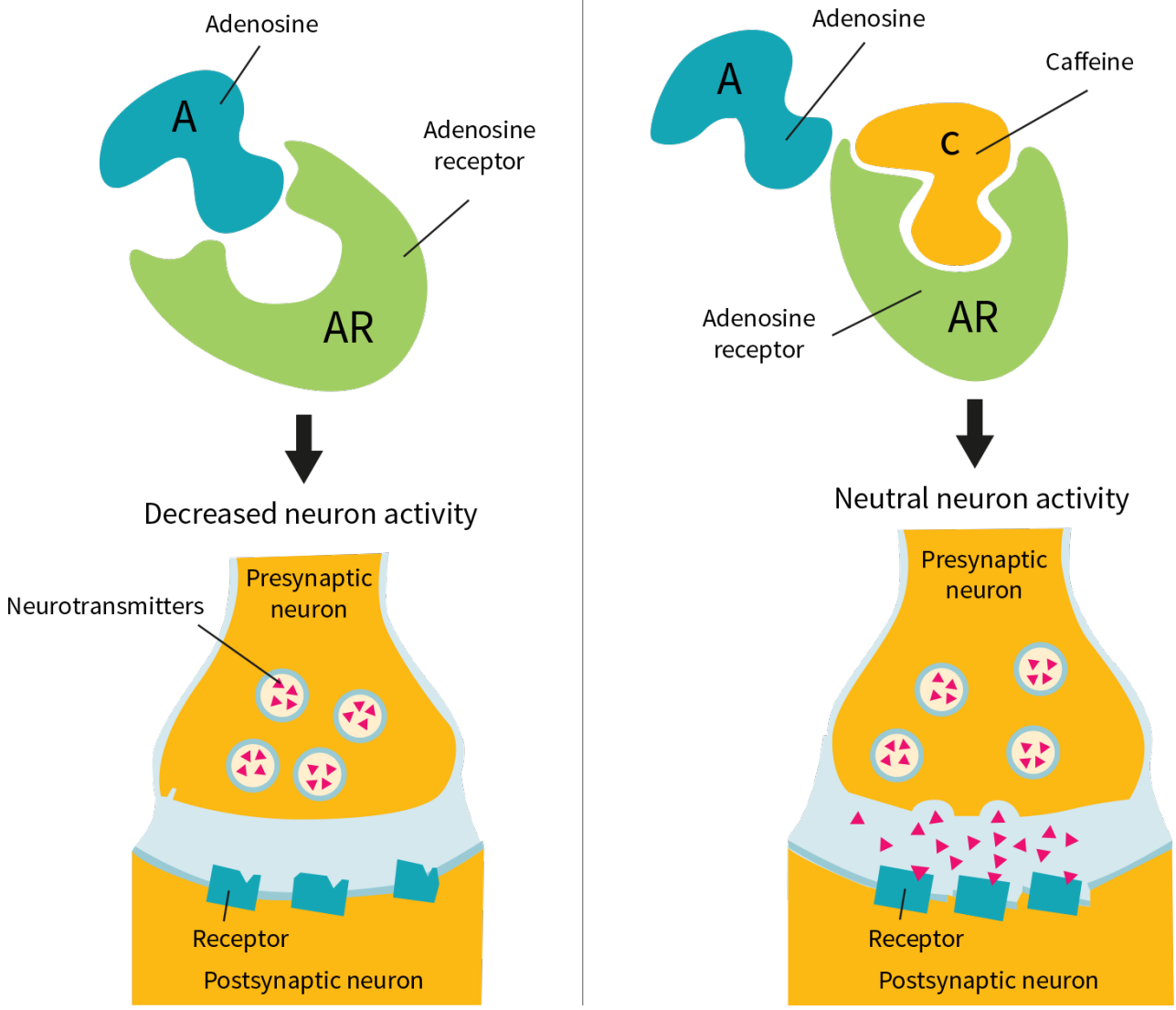
Caffeine with Theanine

What makes *caffeine with theanine* a primary option

Caffeine can block different adenosine receptors in the brain, with varying effects. By blocking the A_1 receptor, caffeine can stave off sleepiness and increase endurance. By blocking the A_{2A} receptor, caffeine can raise the brain's levels of dopamine and epinephrine (aka adrenaline) and thus increase focus and power output.

The mechanism of caffeine





Reference: Ferré. *J Neurochem*. 2008.[90]

Dopamine and epinephrine are two neurotransmitters responsible for the euphoric feeling you remember from your first-ever cup of coffee. Unlike the A_1 receptor, however, the A_{2A} receptor gets desensitized: your production of dopamine and epinephrine downregulates until you need caffeine just to regain your original neurotransmitter levels.

In other words, you become _dependent _on caffeine when you become _tolerant _to some of its effects. Then if you stop taking caffeine, you can experience symptoms of withdrawal, such as fatigue, irritability, headaches, and — ironically — sleeplessness.

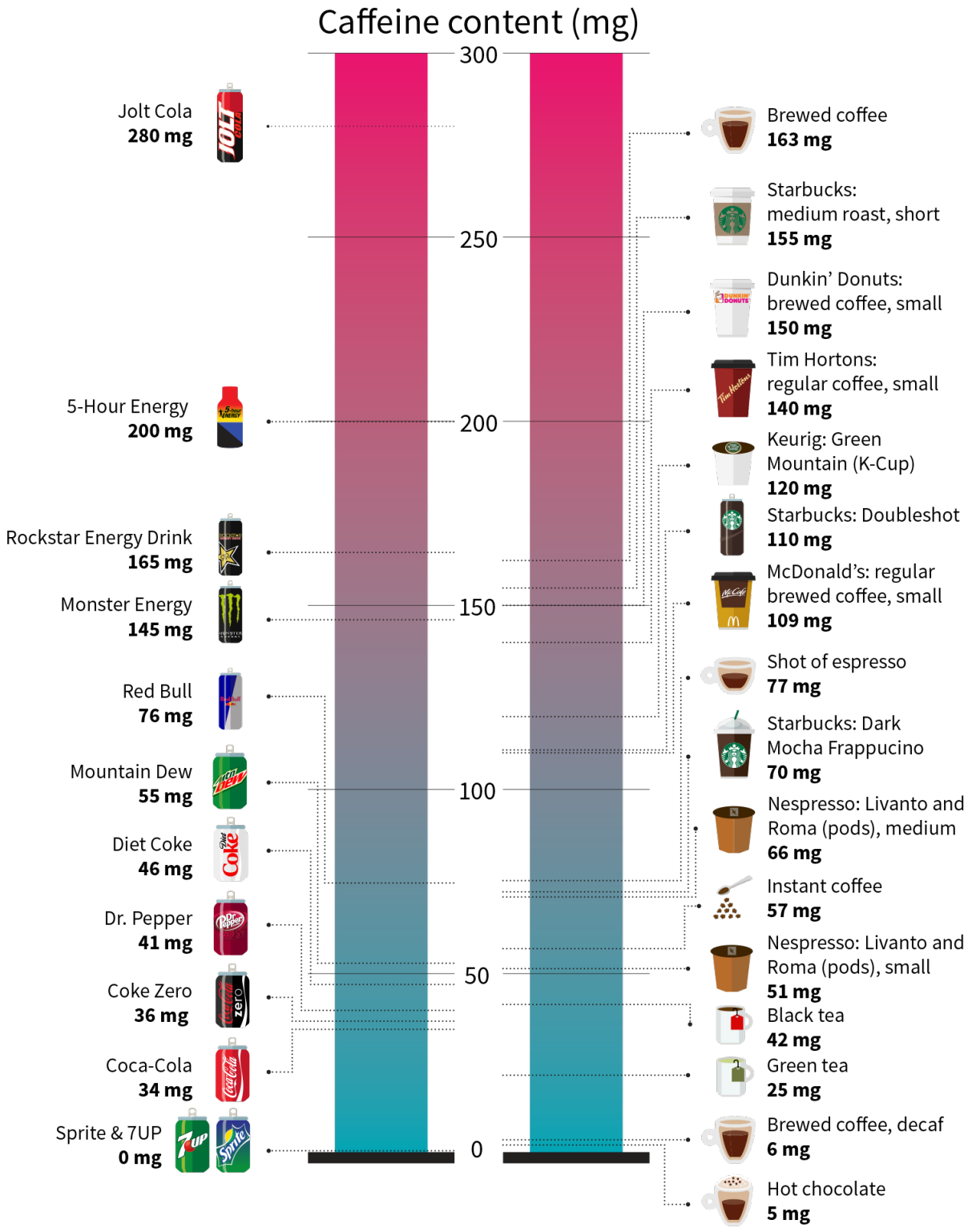
Of the other issues associated with caffeine, we can only mention a few. Caffeine interacts dangerously with several pharmaceuticals, notably tizanidine and a type of antidepressant called *monoamine oxidase inhibitors* (MAOIs). It can also interfere with glucose metabolism, raise blood pressure, raise heart rate, and increase urination (and so the risk of dehydration during exercise, though the effect is usually mild), but those four effects fade away as your tolerance to caffeine develops.

Caffeine can also decrease blood lithium levels. Suddenly eliminating all caffeine from your diet may cause your lithium levels to rise. If you are on lithium medication, keep your day-to-day caffeine intake roughly the same.[91] If you wish to stop taking caffeine, talk with your physician about slowly weaning yourself from it.

You might already be consuming more caffeine than you think. When you calculate your daily intake, consider all your beverages, foods, and supplements. Bear in mind that caffeine can be "hidden" in a product — for instance, if you read "guarana seeds" on a label, remember that those are richer in caffeine than coffee seeds.

Theanine (the amino acid L-theanine) can tame the overexcitability associated with caffeine without reducing caffeine's stimulatory effect. In fact, the improvements in concentration (focus and attention span) from caffeine and theanine respectively are synergistic. Thus, whereas theanine on its own does little to enhance exercise performance, it becomes a primary option when combined with caffeine.

Caffeine content of popular drinks



References: McCusker et al. *J Anal Toxicol.* 2006.[92] ● Desbrow et al. *Nutr Health.* 2019.[93] ● Ludwig et al. *Food Funct.* 2014.[94] ● Fox et al. *J Agric Food Chem.* 2013.[95] ● McCusker et al. *J Anal Toxicol.* 2003.[96] ● Angeloni et al. *Food Res Int.* 2019.[97]

How to take *caffeine with theanine*

For healthy adults, caffeine intakes up to 400 mg/day don't raise any general health concerns. While you _can _consume more, 400 mg is how much caffeine most healthy people can regularly consume in a day without suffering lasting harm.

For a boost in *aerobic* performance, take 100–200 mg of caffeine (up to 400 mg/day) with an equal dose of

theanine half an hour before exercise.

For a boost in *anaerobic* performance, take 400–600 mg of caffeine with 300 mg of theanine half an hour before an especially strenuous workout, no more than twice a week. If tolerance starts to set in, drop down to once a week.

Supplementing caffeine on an empty stomach can increase the rate of absorption, but it can also cause gastrointestinal upset. Caffeine can disrupt sleep when consumed in the evening, or even in the afternoon; even if it does not prevent you from falling asleep, caffeine will impair the *quality* of your sleep. In healthy adults, the average half-life of caffeine falls between 5 and 6 hours, but this number can vary greatly between individuals, because of genetics and other factors — heavy smoking can double the rate of caffeine metabolism, pregnancy can halve it, etc.

Promising Supplements

Adaptogens

What makes *adaptogens* a secondary option

Adaptogens are supplements that can reduce the mental and physical effects of stress, including fatigue, depression, and anxiety. The most popular and well-researched are *Panax ginseng*, *Rhodiola rosea*, and *Withania somnifera* (ashwagandha). These herbs have been the subjects of many studies, but rarely in the context of increased muscular power and never as pre-workout supplements. Preliminary evidence suggests that they can lower the perception of fatigue when taken before exercise, but more research is needed to confirm this effect.

Most studies on ashwagandha used KSM-66. This water-based extract standardized to 5% withanolides has been shown to lower cortisol levels and increase strength and muscle mass.

Some common adaptogens

Panax ginseng | Rhodiola rosea | Withania somnifera (Ashwagandha)

The roots are what is normally used in supplements derived from these plants

How to take *adaptogens*

To supplement *ashwagandha*, take 300 mg of the KSM-66 extract twice a day (i.e., 600 mg/day), including one dose 30–60 minutes before exercise. Alternatively, take your whole 600-mg daily dose 30–60 minutes before exercise. Should you purchase another extract standardized to withanolide content, aim for 30 mg of withanolides per day. If you only have access to the root powder, try 5 g/day.

To supplement *Panax ginseng*, take 200–400 mg of an_ _extract containing 1–3% ginsenosides 30–45 minutes before exercise.

To supplement *Rhodiola rosea*, take 80–160 mg of SHR-5 (an extract standardized to 3% rosavins and 1%

salidroside) 30–45 minutes before exercise. Up to 500 mg can be taken in anticipation of a particularly stressful event.

Branched Chain Amino Acids (BCAAs)

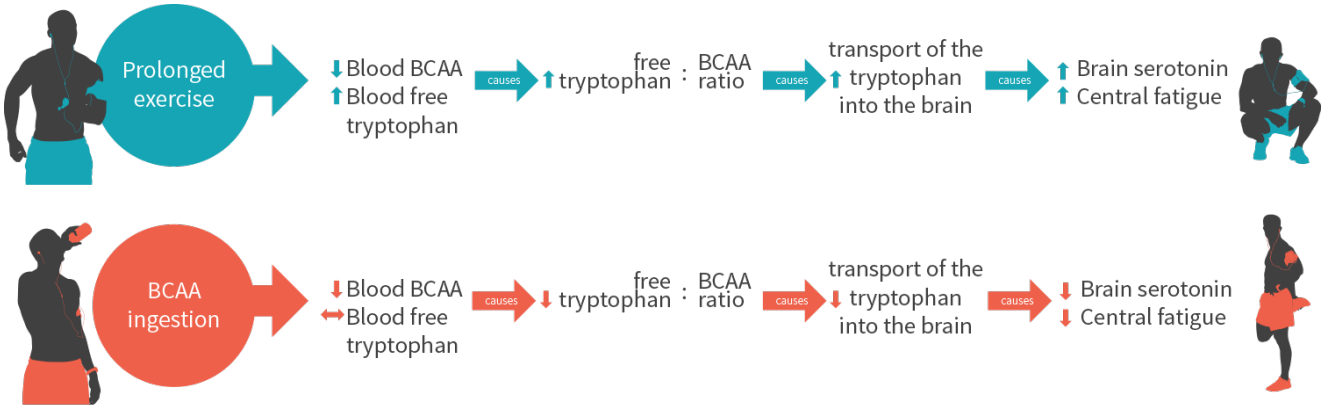
What makes *BCAAs* a secondary option

Proteins are composed of amino acids, some of which your body can make and others it cannot. The ones you need to ingest, because your body cannot synthesize them, are called essential amino acids (EAAs). BCAAs are three of the nine amino acids essential to humans: isoleucine, leucine, and valine.

Since you ingest BCAAs each time you ingest protein, supplementing BCAAs in isolation is mostly redundant. For example, 100 g of a whey protein concentrate can contain 11 g of leucine, 6 g of isoleucine, and 6 g of valine, so 23 g of BCAAs (the numbers vary between supplements).

Many studies have investigated the effects of BCAA supplementation on exercise, and these effects proved minimal. Mostly, BCAAs were found to relieve cognitive fatigue during exercise lasting more than 2 hours. This could be useful for athletes who need to maintain hand-eye coordination over a long game (hockey or football players, for instance). In novices, the reduction in cognitive fatigue might also translate into an increase in physical endurance.

How BCAAs might combat central fatigue during exercise



On the whole, BCAAs have only two potential advantages over protein powders.

- *First,* they are less likely to cause cramping or nausea when consumed before exercise.
- *Second,* they are free of tryptophan (an amino acid that might promote exercise-related fatigue).

How to take *BCAAs*

To supplement BCAAs, take 10–20 g before exercise, in water or a sugary drink. A ratio of 2:1:1 (leucine:isoleucine:valine) is often recommended based on two studies that actually used a 2.3:1:1.2 ratio. Both studies compared this 2.3:1:1.2 mix to a placebo (dextrin); different ratios were not compared, so the ideal ratio is unknown.

Cholinergics

What makes *cholinergics* a secondary option

A supplement is said to be cholinergic when it increases the brain's levels of acetylcholine, a major neurotransmitter associated with memory and muscle contractions. Elevated acetylcholine levels in neurons are associated with stronger muscle contractions, but cholinergics themselves are not well-researched in this context. There is currently no strong evidence that cholinergics increase muscular power output.

CDP-choline (citicoline) and alpha-GPC can provide the brain with the choline it needs to produce more acetylcholine (choline bitartrate is much cheaper, but little of it seems to reach the brain[98]). There is some preliminary evidence that alpha-GPC can increase power output, but this result has yet to be replicated.

The cholinergic Huperzine-A can inhibit acetylcholinesterase, an enzyme that breaks down the neurotransmitter acetylcholine; as a result, the brain's levels of acetylcholine increase. Its half-life exceeds 24 hours (i.e., after 24 hours, more than half of the dose you took will still be in your system), so it accumulates in the body when taken daily, which is problematic since long-term studies are scarce. There is a possibility that, over time, the body could adapt by producing more acetylcholinesterase, which would lead to reduced acetylcholine levels and a withdrawal period after huperzine-A supplementation has ceased. While the doses used in the studies (0.2–0.99 mg) were deemed safe in the short term, long-term supplementation cannot be recommended.

How to take *cholinergics*

To supplement *alpha-GPC*, take 300–600 mg 30–45 minutes before exercise.

To supplement *CDP-choline*, take 250–500 mg 30–45 minutes before exercise.

HMB

What makes *HMB* a secondary option

β-hydroxy-β-methylbutyric acid (HMB) isn't an amino acid per se; it is a metabolite of leucine with a slightly inferior ability to stimulate muscle protein synthesis (MPS) and a superior ability to suppress muscle protein breakdown (MPB).[99][100] These effects appear to be similar between the two currently available forms, calcium HMB and HMB free acid (HMB-FA),[101] and have led to HMB being studied in muscle-wasting conditions,[102] such as cachexia and sarcopenia.[103][104]

🔍 ***Digging Deeper:*** **Muscle protein synthesis and breakdown**

Muscle protein synthesis (MP*S*) is the process of building skeletal muscle, whereas *muscle protein breakdown* (MP*B*) is the process of breaking it down. MPB is a necessary part of muscle growth,[105] but for your muscle mass to increase, you need your MPS to exceed your MPB (overall, in the long term).

Whether you exercise or not, your body is going to break down old or damaged muscle fibers to reuse what it can of their constituent *amino acids* (AAs — the components of proteins) to make new muscle fibers, enzymes, hormones, etc. When it comes to using AAs, MPS is among your body's lowest priorities; if your body needs AAs to serve as neurotransmitters, for instance, and you haven't eaten for a long time, it will scavenge even healthy muscle fibers.

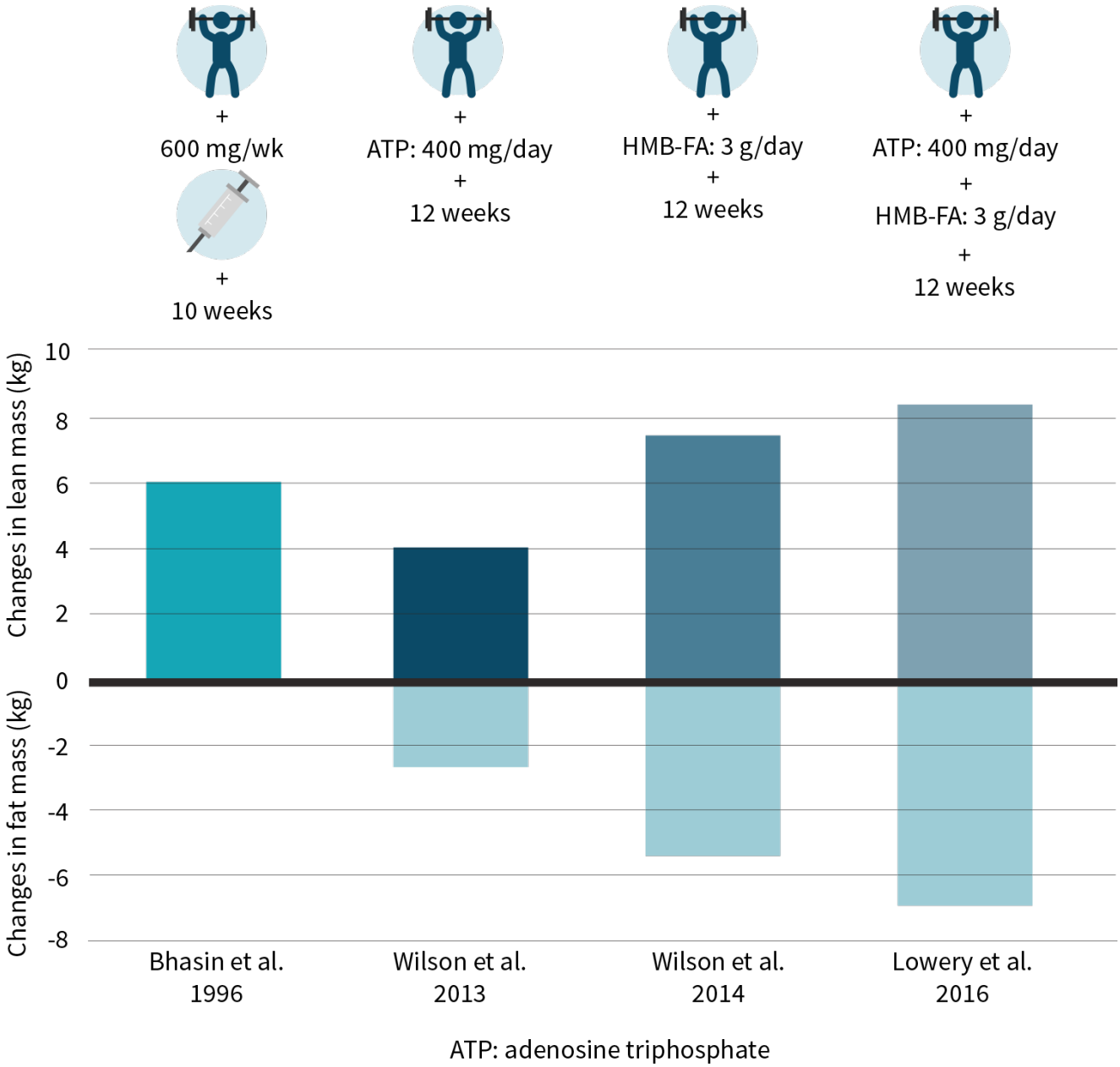
MPS is stimulated primarily by the *essential amino acids* (EAAs), the nine AAs your body cannot synthesize and thus needs to get from food.[106] The quality of a protein is often assessed based on EAA content. Among the EAAs, the three *branched-chain amino acids* (BCAAs — leucine, isoleucine, and valine) are the most potent MPS stimulators,[107][108] with leucine being the most potent of all.[100]

HMB has also been investigated in resistance-trained populations, with some studies reporting massive increases in muscle mass (7.4–9 kg/16.3–19.8 lb over 12 weeks) from 3 grams per day.[109][110][111] However, these findings have come under heavy criticism from experts in the field due to their implausibility and some issues with the data reporting.[112][113]

To put these numbers in perspective, data from 49 studies indicate that protein supplementation during a 12-week resistance-training program increases lean body mass by about 2.2 kg (4.9 lb).[114] Even giving young males supraphysiological doses (doses greater than normally present in the body) of testosterone during a 10-week resistance-training program increased muscle mass by "only" 6.1 kg (13.5 lb).[3]

It is implausible that HMB (with purported muscle gains averaging 0.62–0.75 kg/1.4–1.7 lb a week) is more anabolic than an anabolic steroid (with muscle gains averaging 0.61 kg/1.35 lb a week).

Changes in body composition from ATP, HMB-FA, and testosterone enanthate

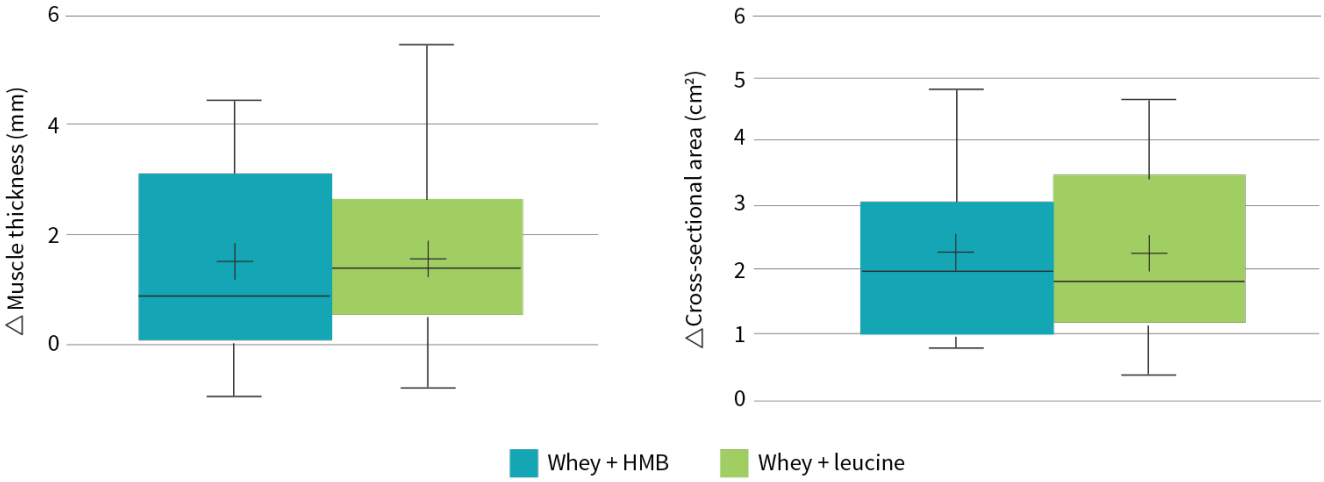


References: Bahsin et al. *N Engl J Med*. 1996.[3] ● Wilson et al. *Nutr Metab (Lond)*. 2013.[115] ● Wilson et al. *Eur J Appl Physiol*. 2014.[110] ● Lowery et al. *J Strength Cond Res*. 2016.[111]

According to a meta-analysis of studies in competitive athletes and experienced weightlifters, 3 grams of HMB daily for 3–12 weeks doesn't affect strength or body composition.[116] Yet a more recent study in competitive athletes (wrestlers, judokas, and practitioners of Brazilian jiu jitsu) did report that HMB increased lean mass (+1.5 kg/3.3 lb) and reduced fat mass (−1.5 kg/3.3 lb) over 12 weeks.[117]

Whether they reported a benefit or not, these studies pitted HMB supplementation against a placebo. When, instead, one group of resistance-trained males took 50 grams of whey protein plus 3 grams of HMB whereas the other took 50 grams of whey protein plus 3 grams of leucine, both groups experienced similar benefits in body composition and muscle size, thickness, and strength.[118]

HMB + whey leads to similar changes in muscle mass as whey + leucine



Adapted from Jakubowski et al. *Med Sci Sports Exerc*. 2019.[118]

By reducing muscle protein breakdown, HMB might allow for faster recovery time both during and between workouts, leading to faster increases in performance. People just starting to exercise and people undertaking high volumes of work are most likely to benefit from HMB. However, HMB does not appear to meaningfully affect the strength or body composition of athletes or resistance-training adults.

How to take *HMB*

Take 3 g of HMB (calcium HMB or HMB-FA) per day. On workout days, take the whole daily dose 1 hour before exercise.

Note that it may take you up to 2 weeks to feel the full effects of HMB, particularly if you are engaging in high-intensity workouts.

🔍 ***Digging Deeper:*** **HMB free acid vs. calcium HMB**

HMB supplements typically come in two forms: the calcium salt form, referred to as calcium HMB, and the HMB free acid form (HMB without the calcium salt attached).

Calcium HBM is the most commonly available (and studied) form. When timing HMB around your workout, calcium HMB is not absorbed as quickly or as well as HMB-FA.[119] It takes 1.5 to two or more hours before calcium HMB peaks in the bloodstream, compared to just 30 minutes with HMB-FA. The absorption of HMB-FA is also greater, resulting in almost twice the concentration in the bloodstream when comparing respective peaks. However, it is not yet known if timing for either supplement form plays a critical role in its effect on exercise performance.

Nitric Oxide Boosters

What makes *nitric oxide boosters* a secondary option

Elevated *nitric oxide* (NO) levels are associated with improved blood flow, muscle growth, and more efficient energy production. NO boosters form a category of supplements meant to increase NO levels in the body. Some common NO boosters are arginine, citrulline, and agmatine. Nitrates from beetroot and leafy green vegetables are not included in this category.

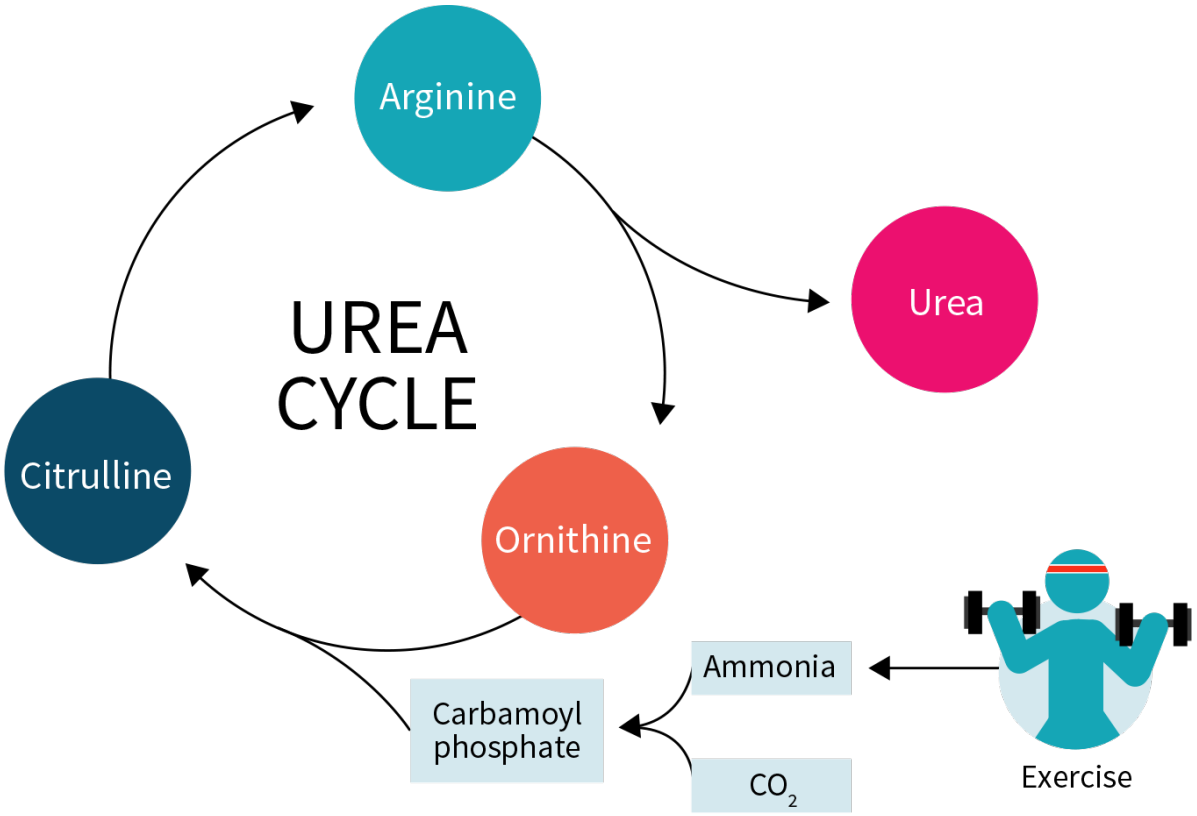
Unfortunately, arginine, citrulline, and agmatine all have issues.

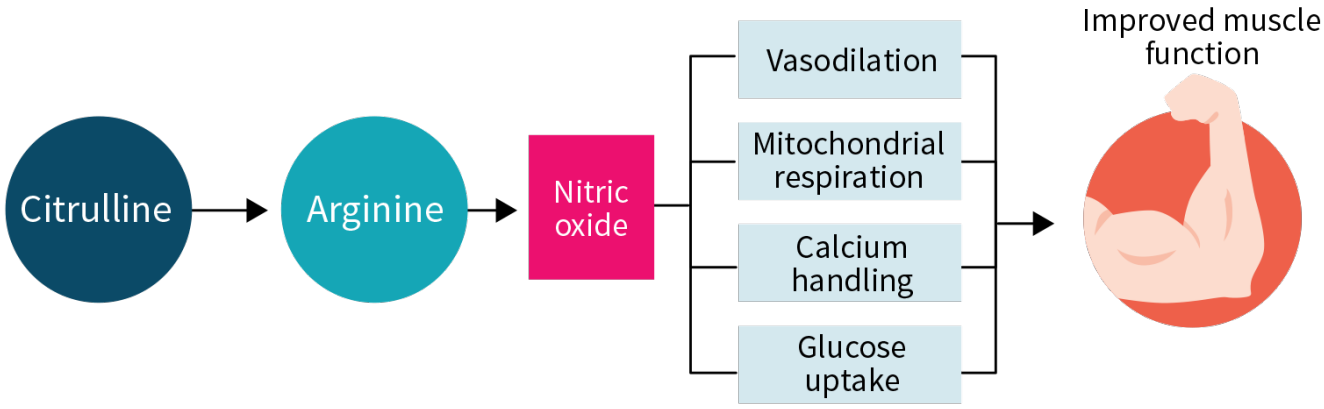
Arginine is the *nonessential amino acid* (NEAA) from which NO is made. Absorption of arginine by the intestines is limited, and much is eliminated from the body before it can reach the muscles. In healthy individuals, supplementing with 6–10 grams of arginine doesn't appear to affect NO production,[120] blood flow to muscle tissue,[121] MPS,[122] or strength performance.[123]

Citrulline is usually sold as citrulline malate, a combination of L-citrulline and malic acid. It is a *nonprotein amino acid* (NPAA) that is better absorbed than arginine and is converted into arginine in the kidneys in a controlled manner (rather than a huge spike in NO levels, you can expect a steady increase of lesser magnitude). Supplementation does boost serum levels of both arginine and NO — but its effects on exercise performance are less clear.[124][125] Several studies in resistance-trained males and females reported that preworkout citrulline malate benefited weightlifting performance and, in the following days, reduced muscle soreness,[126][127][128][129] but studies in untrained or moderately trained adults reported no benefit.[130][131][132] Additionally, in resistance-trained males, chronic supplementation with L-citrulline or citrulline malate had no effect on body composition or muscle strength.[133]

Agmatine is a newer, promising supplement, but one that lacks decent human evidence for its exercise-enhancing effects.

Citrulline's roles in exercise physiology





Today's NO boosters have been marketed based on promising evidence, but their effects may be unreliable on an individual basis. They should only be considered for supplementation if dietary nitrates are not an option. In that case, citrulline is the best alternative.

Note: NO boosters should not be taken with yohimbine, for they counteract the effects of this fat burner (unlike nitrates, which increase NO through another pathway).

How to take *nitric oxide boosters*

Half an hour before exercise, take 6 g of *citrulline* (or 10 g of citrulline malate). Thanks to better absorption rates, intestinal side-effects are less likely than with arginine.

Because glutathione may slow down the rate of NO breakdown in the bloodstream, adding 200 mg of *N-acetylcysteine* (NAC) to your nitrates might prove synergistic.

Sodium Bicarbonate

What makes *sodium bicarbonate* a secondary option

Sodium bicarbonate (aka baking soda) is a supplement that provides dietary bicarbonate, which can increase blood levels of bicarbonate (normally produced by the kidneys) and subsequently buffer acid production in the body. The main mechanism of action of sodium bicarbonate is in negating the effects of acidosis, which can impair muscular performance.

The bicarbonate buffer system

During periods of exercise, the body will produce greater amounts of hydrogen ions (H+), which is acidic and can decrease performance.

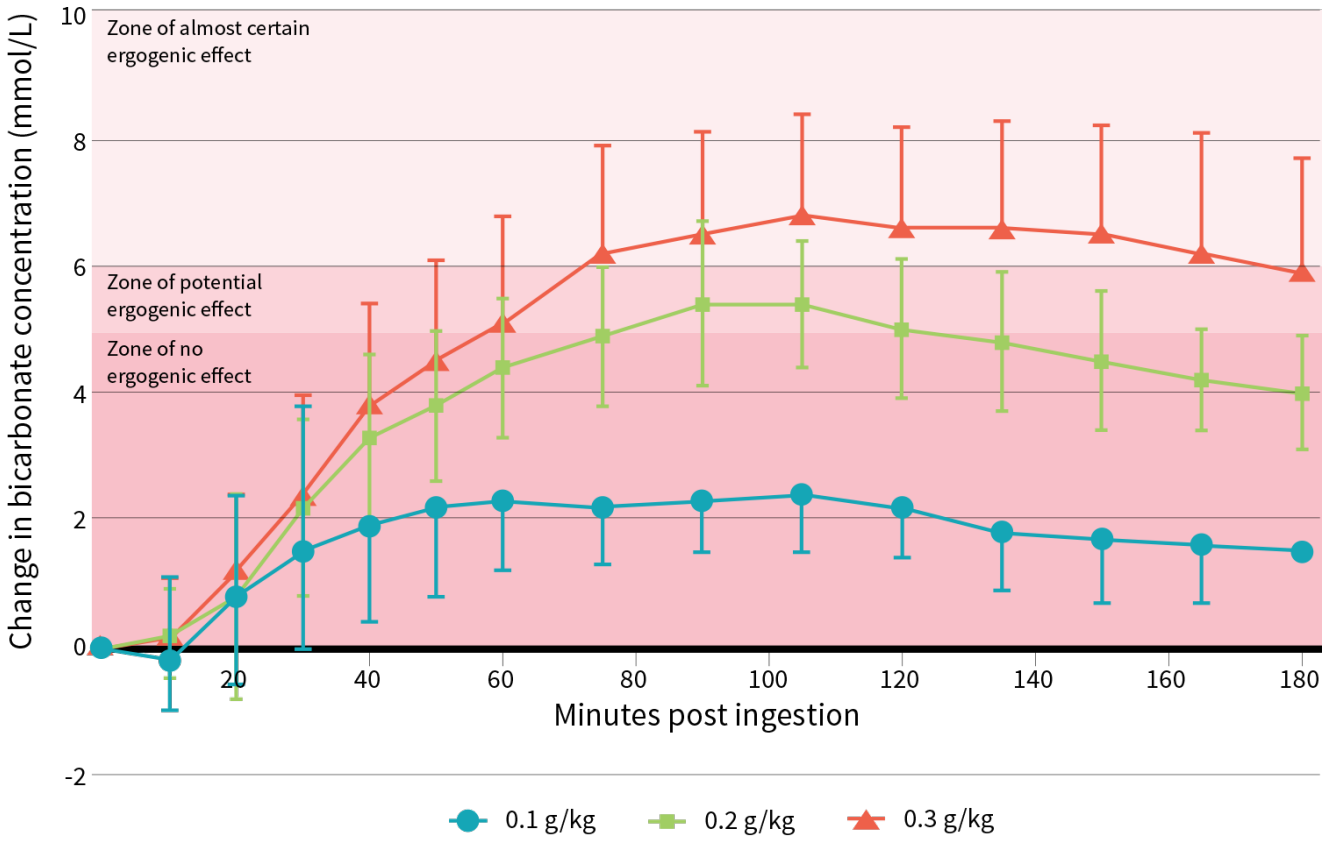
Sodium bicarbonate can buffer these acids by binding with them, which begins a process through which acidity can be decreased.

This acid buffering can prolong energy metabolism in the muscle cells during exercise, which can translate into a more sustained power output.

Several dosing strategies have been studied and implemented among athletes,[134] but 0.3 grams per kilogram of bodyweight is the most common dose to reap the benefits, when ingested 60–90 minutes prior to exercise.[135][136]

These doses typically increase blood bicarbonate levels by about 20–25% or about 5–6 mmol/L from baseline.[137] Time to peak blood concentrations vary depending on what the individual has eaten, rate of gastric emptying, and other factors. This dosing strategy has been shown to adequately enhance buffering capacity, which in turn can help you train harder as a result of the delayed onset of metabolic acidosis — the "burn" — which characterizes certain forms of intense exercise. Dosages of 0.5 g/kg of body mass have been shown to be slightly more effective than the 0.2–0.3 g/kg range, but intake at this level also tends to induce gastrointestinal discomfort, including stomach bloating, nausea, and diarrhea.[134]

Dose-response of sodium bicarbonate



Reference: Jones et al. *Int J Sport Nutr Exerc Metab*. 2016.[136]

How to take *sodium bicarbonate*

There is ample evidence showing that ingestion of 0.3 g/kg is likely to increase blood bicarbonate concentrations enough to achieve an ergogenic benefit (attenuated muscle fatigue,[138] improved contractile performance,[139] and an increase in 'perceived readiness' prior to exercise[140]). But benefits are dependent on proper dosing and timing.

With respect to athletic performance and dosing strategies, individuals needing to ingest sodium bicarbonate less than 30 minutes prior to exercise can take smaller doses (0.1–0.2 g/kg) without the risk of gastrointestinal discomfort that is common in higher acute doses. For athletes taking higher doses of 0.3 g/kg or more, based on the mean times to reach peak blood concentration, ingestion should take place approximately 1 to 1.5 hours before the onset of exercise.

Sodium bicarbonate intake

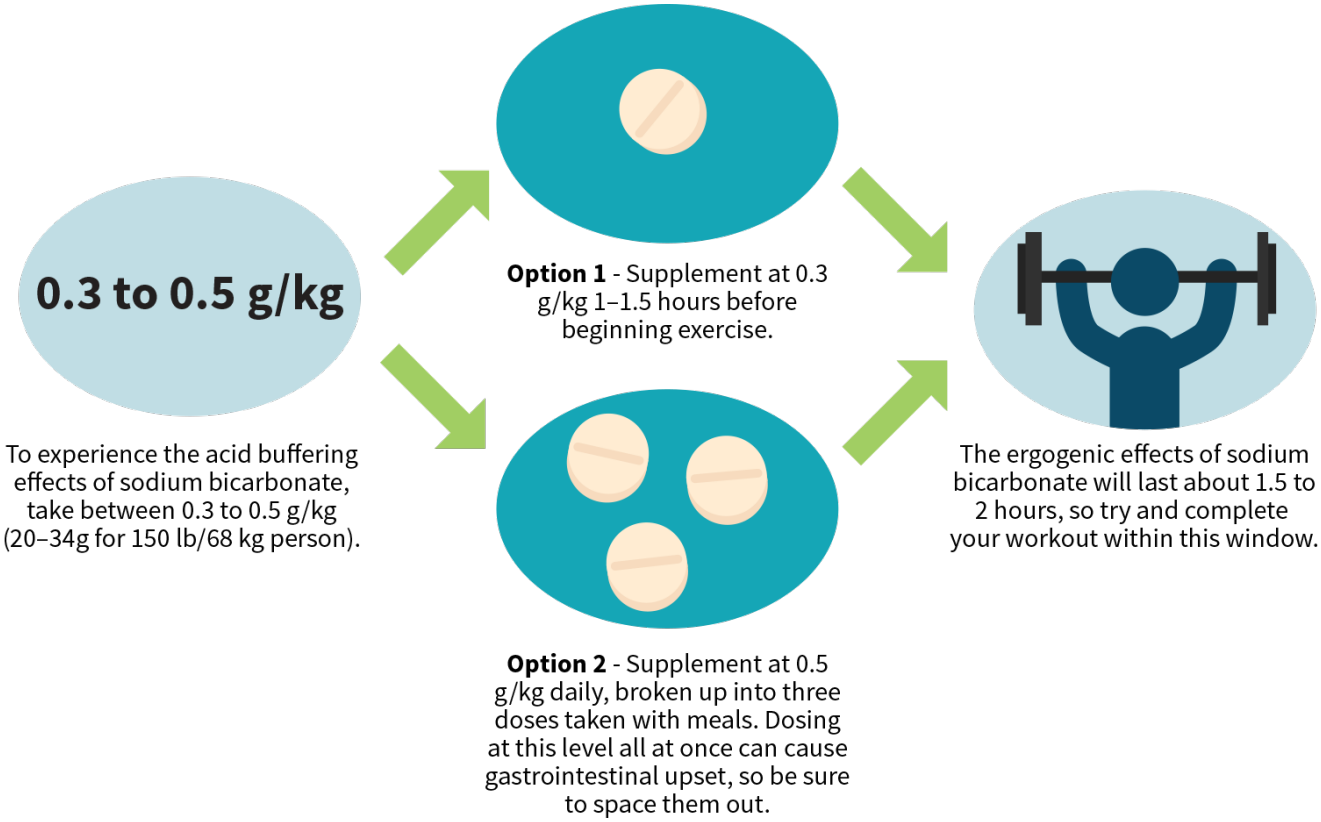
BODY WEIGHT	BODY WEIGHT	0.05	0.09	0.14	0.18	0.23	g/lb
LBS	KG	0.10	0.20	0.30	0.40	0.50	g/kg
100	45	4.5	9.0	13.5	18.0	22.5	g
125	57	6.0	11.5	17.0	22.5	28.5	g
150	68	7.0	13.5	20.5	27.0	34.0	g
175	79	8.0	16.0	23.5	31.5	39.5	g
200	91	9.0	18.0	27.0	36.5	45.5	g

BODY WEIGHT	BODY WEIGHT	0.05	0.09	0.14	0.18	0.23	g/lb
LBS	KG	0.10	0.20	0.30	0.40	0.50	g/kg
225	102	10.0	20.5	30.5	41.0	51.0	g
250	113	11.0	22.5	34.0	45.0	56.5	g
275	125	12.5	25.0	37.5	50.0	62.5	g

Gastrointestinal upset can sometimes limit the use of sodium bicarbonate. Individuals who experience GI upset with higher doses require co-ingestion of sodium bicarbonate with food or fluid in order to reduce such symptoms. Keep in mind that one dose can be 200% or more of your daily recommended sodium intake. Sodium bicarbonate and beta-alanine (aka β-Alanine) have similar effects, but there is limited evidence if one is better than the other (although they might be synergistic).

For doses of 0.3 g/kg BM, dividing the dose into two or three doses throughout the day, and/or taking it with meals can ameliorate the nasty GI effects of acute high doses of sodium bicarbonate, though it ultimately depends on the individual's tolerance.[141] Alternatively, 0.2 g/kg might be a the sweet spot to avoid GI-related adverse effects and still experience some ergogenic benefits.

Possible sodium bicarbonate dosing strategies



Taurine

What makes *taurine* a secondary option

The amino acid L-taurine gave its name to Red Bull (*taurus* is Latin for "bull") and can also be found in other energy drinks. It is a sulfur-containing amino acid not involved in protein synthesis but omnipresent in your

body. There is some evidence to support its use to enhance exercise performance, but more so in people with heart failure.

In young athletes, 1–6 grams of taurine improved endurance exercise performance regardless of how much taurine was taken or for how long.[142] This suggests that 1 gram is as effective as 6 and that chronic supplementation isn't necessary (just take your dose before your workout).

Taurine is also believed to benefit older adults with sarcopenia through its effects on protein metabolism, oxidative stress, and inflammation.[143] But this belief is based primarily on mechanistic evidence from studies in animals and test tubes, meaning the idea remains hypothetical until human studies are conducted.

Similarly, there are various levels of evidence that taurine supplementation may help with many other disease states, including neurodegenerative diseases, eye diseases, diabetes, heart failure, high blood pressure, and muscular dystrophy.[144] These conditions are associated with taurine depletion, so supplementation might help by restoring normal levels.

How to take *taurine*

Take 1–3 grams 15 to 30 minutes prior to an endurance workout, with or without food. Do not take more than 3 g/day.

Taurine supplementation may also reduce the muscle cramping associated with fat burners.

Unproven Supplements

Glutamine

What makes *glutamine* an unproven option

Glutamine is an amino acid that plays an important role in muscle cells. In fact, _in vitro _studies (studies done in a test tube or a petri dish) require glutamine to keep cells alive. When glutamine is added to muscle cells *in vitro*, protein synthesis increases.

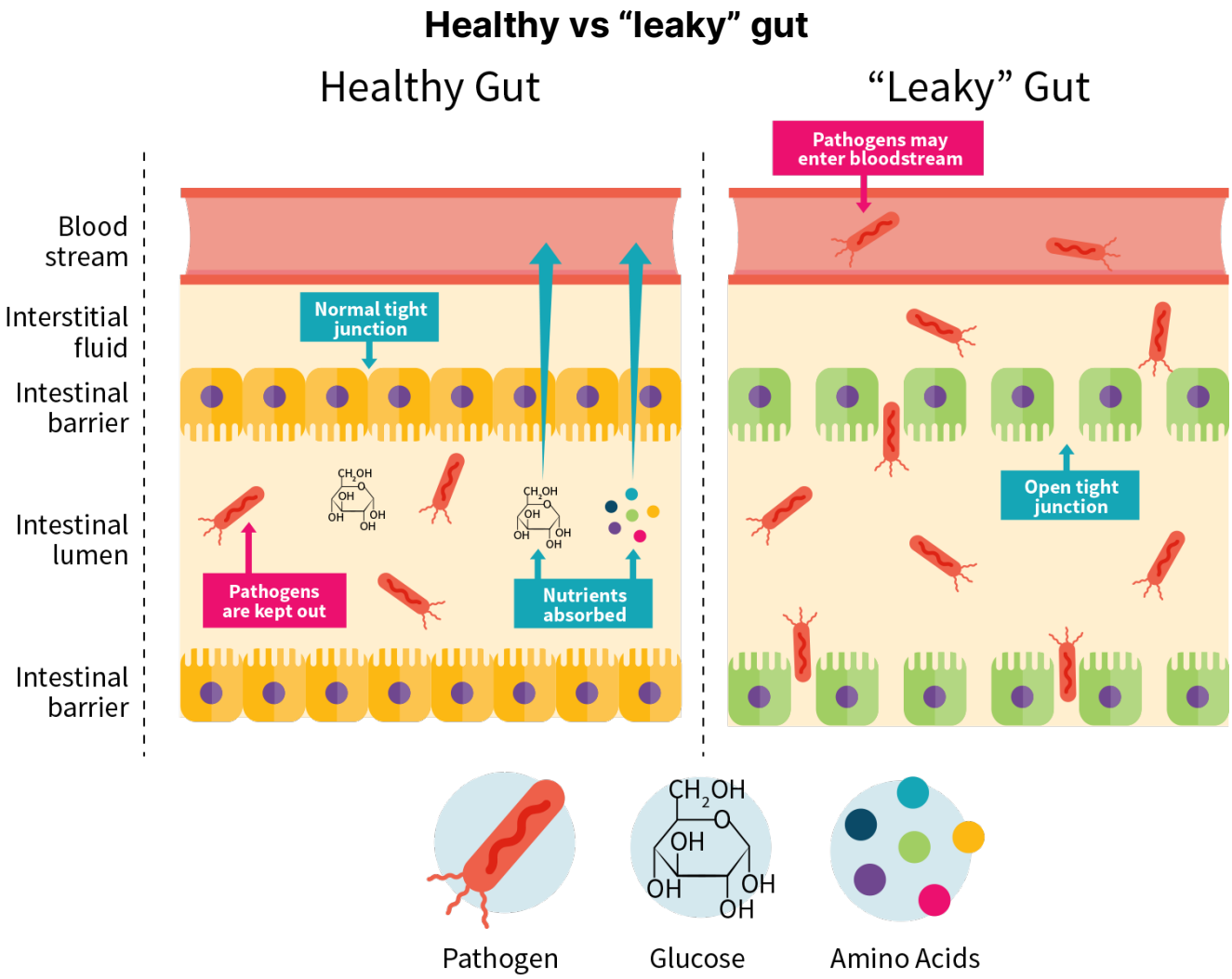
One of glutamine's roles in your body is to help get leucine inside your cells. It does so by entering a cell on its own then leaving it using a transporter that simultaneously pulls in leucine. Basically, when the cell kicks out glutamine, it brings in leucine. This process is necessary for the stimulation of *mammalian target of rapamycin* mTOR, one of the main anabolic pathways) and protein synthesis.[145]

The prominent role played by glutamine in amino acid transport and protein synthesis brings up the question of whether glutamine supplementation can enhance muscle growth or exercise performance.

A handful of studies have investigated the effects of glutamine supplementation on body composition, and a meta-analysis of these studies found no benefit.[146] Even the study using the highest dosage of 0.9 g/kg/day in resistance-trained adults found no effect.[147] There may be a benefit to exercise recovery,[147] especially when glutamine is combined with leucine,[148] but more research is needed for confirmation.

Endurance athletes who train a lot may benefit in another way, though. Glutamine plays an important role in immune function (it is notably the primary fuel source of white blood cells).[149] After prolonged endurance exercise, plasma glutamine levels are reduced, which correlates with an increased risk of infection.[150] Glutamine supplementation may help prevent or lessen this increase.

Relatedly, prolonged endurance exercise is known to cause "leaky gut", a condition in which heat stress and reduced blood flow to the gastrointestinal tract cause intestinal cell damage.[151] This damage loosens tight junctions between cells, allowing for the absorption of things that are not supposed to pass through the intestinal barrier (e.g., proinflammatory endotoxins).



Glutamine supplementation reduces exercise-induced intestinal permeability and the resulting increase in serum endotoxin and inflammatory markers.[152][153] At least one study in patients with Crohn’s disease (a type of inflammatory bowel disease) has reported that glutamine and whey protein similarly reduce intestinal permeability and damage.[154] Note, however, that whey protein contains glutamic acid (aka glutamate), _not _glutamine, though your body can make the latter out of the former.

The data are promising, but more human clinical trials are needed to confirm this effect.

Testosterone Boosters

What makes *testosterone boosters* an unproven option

There is precious little human evidence to support the efficacy of testosterone boosters. Studies are seldom replicated, and when replicated seldom draw the same conclusions. Furthermore, even if a supplement can coax your body into producing more testosterone, it can only do so within your physiological limits — do not expect steroid-like effects.

Some supplements claiming to boost testosterone — including maca, fenugreek, and *Tribulus terrestris* — actually enhance libido. This effect can translate into increased confidence, maybe directly (increased libido

= increased confidence), more probably indirectly (increased libido = a feeling that the supplement is working = increased confidence).

The positive influence of confidence on exercise performance has been noted in several dedicated studies, so if libido boosters improve your power output due to improved energy and mood, they may have a role to play in your combo.

Inadvisable Supplements

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

Keep in mind that all muscle builders and exercise performance enhancers are overhyped to some extent. This is a lucrative market, so unsubstantiated claims are numerous. As a rule, avoid "proprietary blends" that can hide from you how much of each ingredient you are actually getting.

FAQ

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

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

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

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

Q. Can I modify the recommended doses?

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

Q. At what time should I take my supplements?

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

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

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

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

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

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

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

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

Q. I have an iron stomach. I have never felt nauseous from supplements. Do I still need to take precautions to avoid gastrointestinal upset?

If you have never had any issues with nausea or vomiting, you may have an easier time ingesting large doses of certain supplements. Nevertheless, it is not a good idea to disregard the warnings on a product.

Q. Why do study results differ for a given ergogenic supplement?

One reason that sports supplements can show benefit in some studies but not others is because there are many different testing procedures that researchers can use to determine if there is an effect from the supplement trial.

For example, studies can test participants using a time-trial (covering a pre-set distance as quickly as possible), time to exhaustion (maintaining a pre-set pace for as long as possible), or repeated sprint tests

(generating as much power as possible each time). Within these different protocols there is a lot of potential variability, like the distance of the time trials, the intensity for the time to exhaustion tests, or the number of repeated sprints to be measured, as well as rest time between efforts, whether the participants are recreational athletes or trained professionals, etc.

Underlying all of these variables are sex differences, as males and females can differ when it comes to fuel sources, metabolism, and specific adaptations to exercise. There are tons of ergogenic supplement trials enrolling only or mostly fit men: for muscle gain, fat loss, and exercise performance. The same is not true for fit females, which is a big issue for evidence applicability.

Q. How long does it take for caffeine tolerance to set in? And how long do I need to go without caffeine for this tolerance to fade away?

It varies, in both cases, depending notably on dosage (amount and frequency) and genetics. Some people become tolerant in days, others in weeks. Some people can reset their tolerance in a week, whereas others may need a couple of months.

In the end, you'll have to experiment to find what works for you. Should you wish to reset your tolerance, take at least two weeks off caffeine, then try a small dose (50–200 mg). If you find the stimulation acceptable, you can resume using caffeine more often; if you don't, take another week off, then try a small dose again.

Do not attempt to fight caffeine tolerance with higher and higher doses. It would be not only dangerous, but also counterproductive, as you'd soon reach an insurmountable tolerance — a tolerance no dose can overcome.

Q. Don't creatine and caffeine negate each other?

Although not all studies agree, a high dose of caffeine (5 mg per kilogram of body weight, so about 2.3 mg/lb) might partially negate the benefits of creatine, but only when both supplements are co-ingested during a creatine loading phase. This potential issue can be sidestepped by consuming your creatine and caffeine several hours apart or by skipping the optional creatine loading phase.

Q. Can I take caffeine without theanine, or vice versa?

Caffeine is an effective stimulant on its own. Adding theanine will enhance your focus. Theanine by itself provides no exercise-related benefit.

Q. Isn't soy protein _bad _for males?

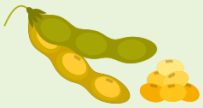
Phytoestrogens are plant compounds structurally similar to estradiol, the main estrogen in males and premenopausal females. Because soy contains isoflavones, a type of phytoestrogen, concern has been raised about soy affecting male health.

To this day, two case reports have documented adverse effects (gynecomastia, hypogonadism, reduced libido, and erectile dysfunction) from an estimated 360 mg of soy isoflavones per day for 6–12 months. However, a meta-analysis of 15 *randomized controlled trials* (RCTs, a much higher level of evidence than case reports) found that males' levels of total and free testosterone were not notably affected by either 60–240 mg of isoflavones or 10–70 grams of soy protein per day.

Accordingly, a couple of scoops of soy protein powder are unlikely to have estrogenic effects in males. If you'd like to take more, however, look for a soy protein concentrate or isolate produced through the alcohol-wash method, which dramatically lowers the isoflavone content.[155]

Keep in mind that the isoflavone content of different soy products can vary depending on several factors, such as the variety of soybeans used, differences in growing and storage conditions, and differential food processing techniques employed.[156] You can see how it varies below.

Isoflavone content of common soy foods

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

Reference: USDA FoodData Central Databases. Accessed Jan 18, 2019

Q. Don’t dietary proteins *reduce* bone density?

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

- Your body draws from its calcium stores (in bones) to buffer the acid load caused by dietary protein. This has led researchers to suggest that higher protein intake could increase bone loss.[157]
- Most studies that looked at protein intake and calcium excretion list dairy products as a protein source,[158] so higher urinary calcium could simply be the result of higher calcium intake (i.e., more calcium in, more calcium out).

Therefore, looking only at calcium _excretion _wasn't enough. Subsequent studies showed that dietary protein promotes dietary-calcium absorption[159] and that high protein intake "promotes bone growth and retards bone loss whereas low-protein diet is associated with higher risk of hip fractures."[160] High-protein diets have also been shown to modestly suppress the decrease in bone mineral density caused by weight loss.[161]

What happens is that when you ingest more protein, you absorb more of the calcium in your food, so less calcium ends up in your feces. Later, your body gets rid of the calcium it doesn't need, so more calcium ends up in your urine, but not as much as would have otherwise ended in your feces.[162] Therefore, an increase in protein intake leads to an overall decrease in calcium excretion, which points to an increase in calcium retention. High-protein diets also raise your *insulin-like growth factor-1* (IGF-1),[163] which promotes notably bone growth.[164]

All in all, current evidence suggests that *protein's effect on bones is either neutral or beneficial*.[162][165]

Q. Why do you have entries for BCAAs and HMB but not leucine?

BCAAs might alleviate cognitive fatigue when taken before a game, so they have a niche to fill. There is some evidence that HMB could be more anti-catabolic as the same amount of leucine when calories are restricted, in which case it would also have a niche to fill. With regard to anabolism, increasing your protein intake is more likely to help than leucine alone, so leucine doesn't really have a niche to fill.

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

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

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

Since carnosine simply gets broken down into β-alanine and histidine,[166] and since your muscles already have enough histidine, carnosine supplementation has no advantage over β-alanine supplementation[167] — especially since β-alanine is cheaper.

Q. Are sodium bicarbonate and β-alanine doing

the same thing or can they be used synergistically?

Sodium bicarbonate is primarily an extracellular buffer,[168] while carnosine is primarily intracellular. In one study, the combination of both β-alanine and sodium bicarbonate supplementation may exert a synergistic influence, alleviating muscle fatigue and improving performance more than when supplemented alone.[169]

Q. Why take NAC to make glutathione? Why not take glutathione directly?

Oral glutathione gets digested into its constituent amino acids: cysteine, glycine, and glutamic acid. Of those three, cysteine is the rate-limiting factor in endogenous glutathione production. Oral *N-Acetylcysteine* (NAC) is simply a more efficient (and cheaper) way of providing your body with cysteine. Multiple studies have reported greater increases in circulating glutathione from oral NAC than from an equal dose of oral glutathione.

Q. Can I get enough nitrates from fruit?

In short, no. Even "nitrate-rich" fruits, such as melons and strawberries, pale in comparison to most vegetables. Compare, for instance, 100 g of beetroot (199.2 mg of nitrates) with 100 g of melon (32.5 mg), strawberries (17.2 mg), banana (7.6 mg), apple (2 mg), or orange (0.9 mg).

Q. I've heard that I should "load" creatine. What does that mean?

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

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

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

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

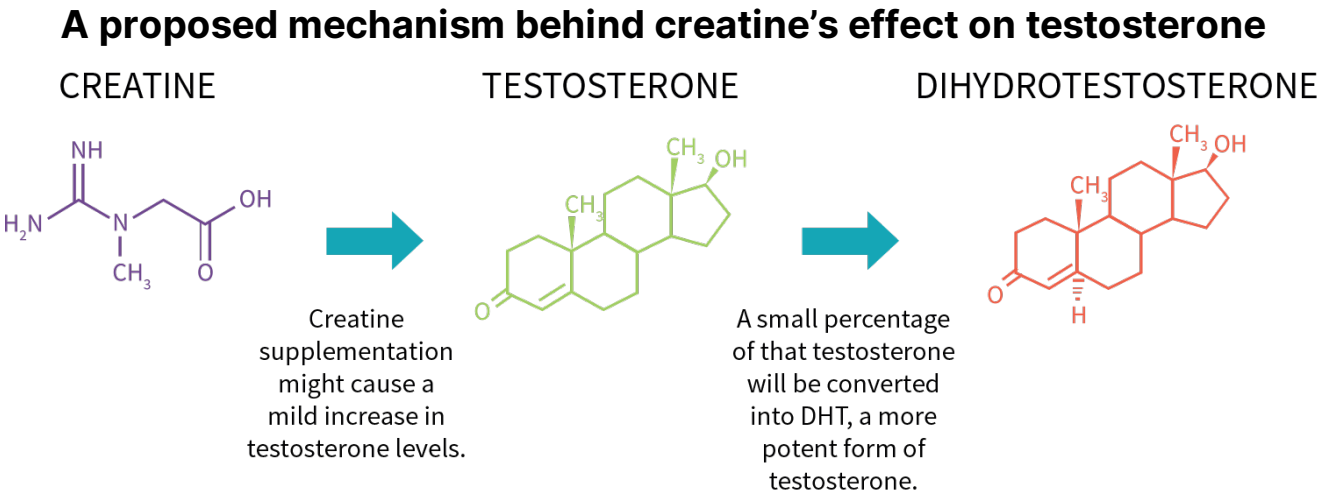
Note that even if supplemental creatine fails to enter your muscles it can still benefit you in other ways,

such as by improving your body's methylation status (methylation being a way for your cells to help manage gene expression).

Q. Will creatine cause hair loss?

The idea that creatine *might* increase hair loss stems from a single randomized controlled trial (RCT) whose participants (20 healthy, young, male rugby players) saw a small but statistically significant increase in *dihydrotestosterone* (DHT) after supplementing with creatine for 21 days.[20] When DHT, a potent metabolite of testosterone, binds to DHT receptors on the hair follicles of the scalp, those follicles may shrink and stop producing hair.[170][171]

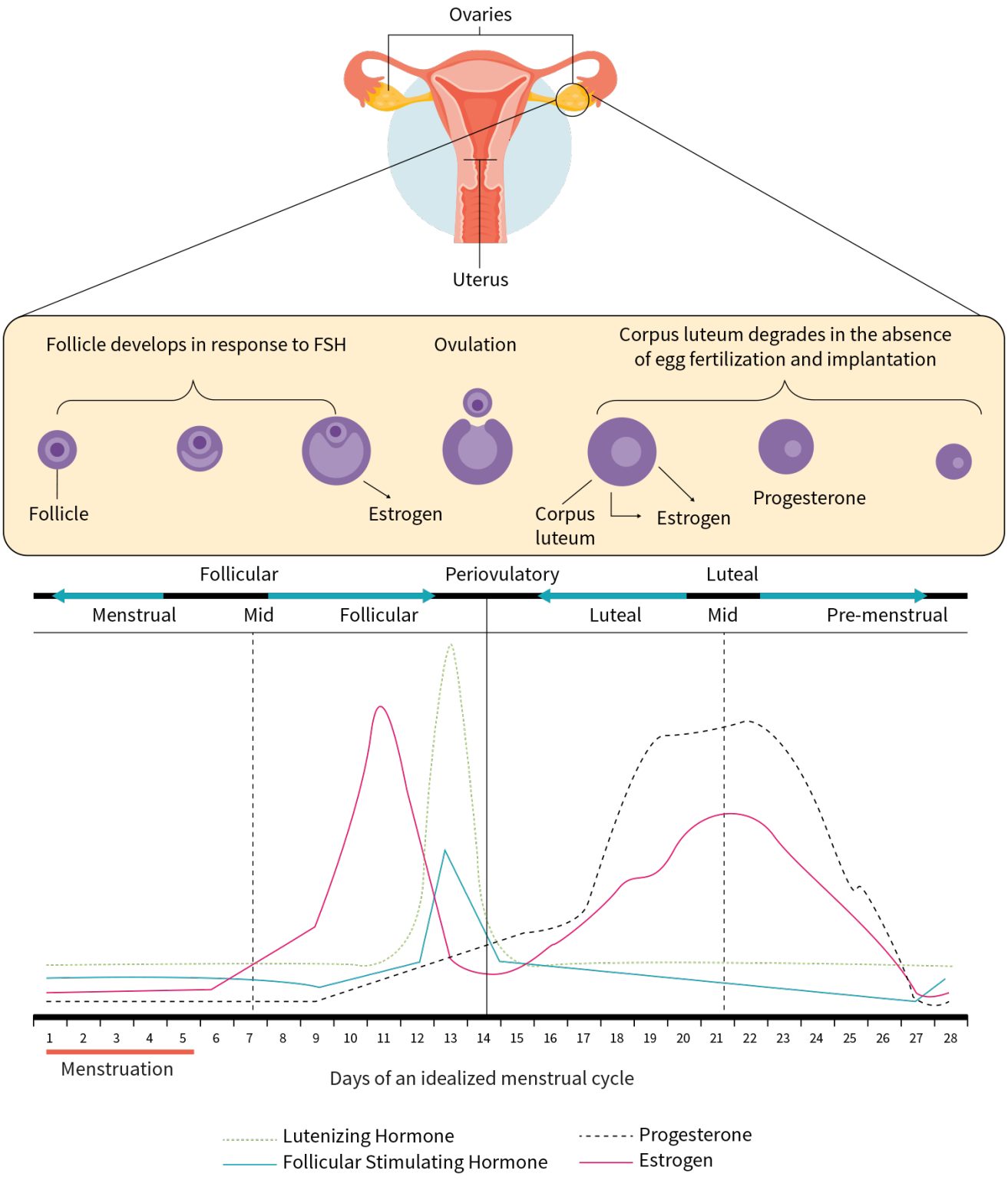
To date, this RCT is the only one to have tested creatine's effects on DHT. However, a number of RCTs have examined creatine's effects on testosterone. Out of 12 additional RCTs, two saw a significant increase in testosterone,[21][22] but 10 saw no effect.[20][172][23][24][25][26][27][28][29][173] Of those 12 RCTs, five also tested creatine's effects on free testosterone, the form that gets converted into DHT, and all saw no significant increases.[172][23][25][27][29]



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

Q. Does the menstrual cycle affect caffeine's performance-enhancing properties?

Caffeine is a popular ergogenic aid, the performance-enhancing effects of which have been confirmed in the scientific literature. However, the vast majority of the available trials have been conducted in males, with most of the interventions that have been conducted in females having tested the ergogenic properties of caffeine during the follicular phase of the menstrual cycle, which possibly minimized the potential effects of hormonal variations on a given studies performance outcomes (speed, strength, etc).



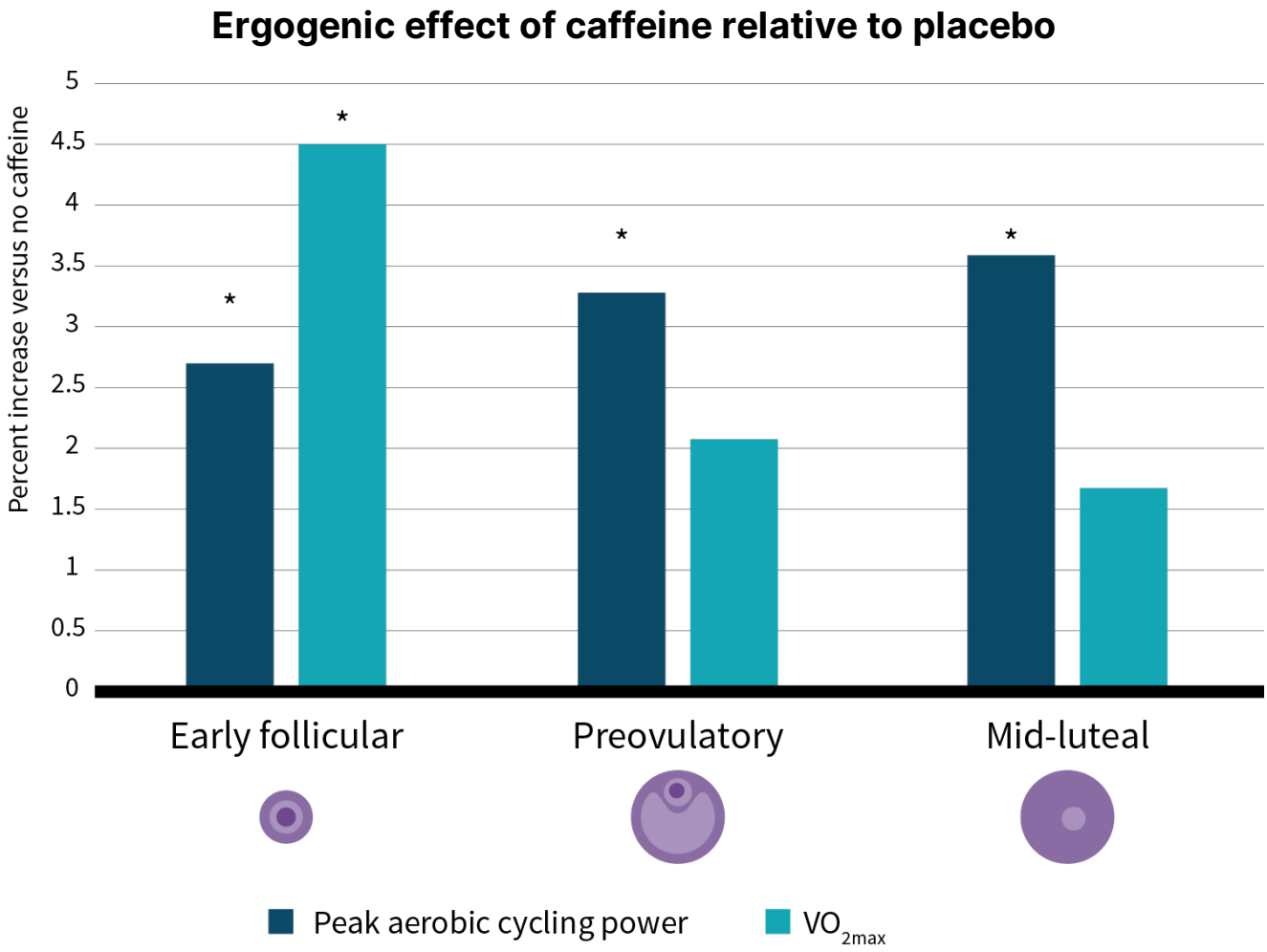
Adapted from Draper et al. *Sci Rep*. 2018.[174]

While the magnitude of the ergogenic effect of caffeine may potentially vary during the different phases of the menstrual cycle, only one study has examined this possibility. This clinical trial examined the ergogenic effects of caffeine ingestion in females during different phases of the menstrual cycle.[175]

In this four-week, double-blind, randomized, crossover trial, 13 well-trained young females ingested a capsule containing either caffeine (3 mg/kg of bodyweight, which was around 180 mg, in this case) or placebo 60 minutes before an exercise bout on two separate experimental trials in each of the following three phases of the menstrual cycle for a total of six identical experimental trials.

- Early follicular

- Preovulatory
- Mid-luteal



Q. How does resistance training affect testosterone levels?

In general, serum testosterone rises immediately following resistance training in males, but returns to baseline, or even below baseline, after about 30 minutes.[176] Several factors may affect the specific testosterone response to working out, however. For instance, high intensity or high volume alone isn't enough to induce a testosterone response. A response is induced by meeting a minimum threshold for both.

In females, some studies have also found short-term increases in serum testosterone, but others haven't, so the results are more equivocal.

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