MENNO HENSELMANS

Science to master your physique

HEALTH & FOOD CHOICES

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Contents

➢ Lecture [optional]

Health science

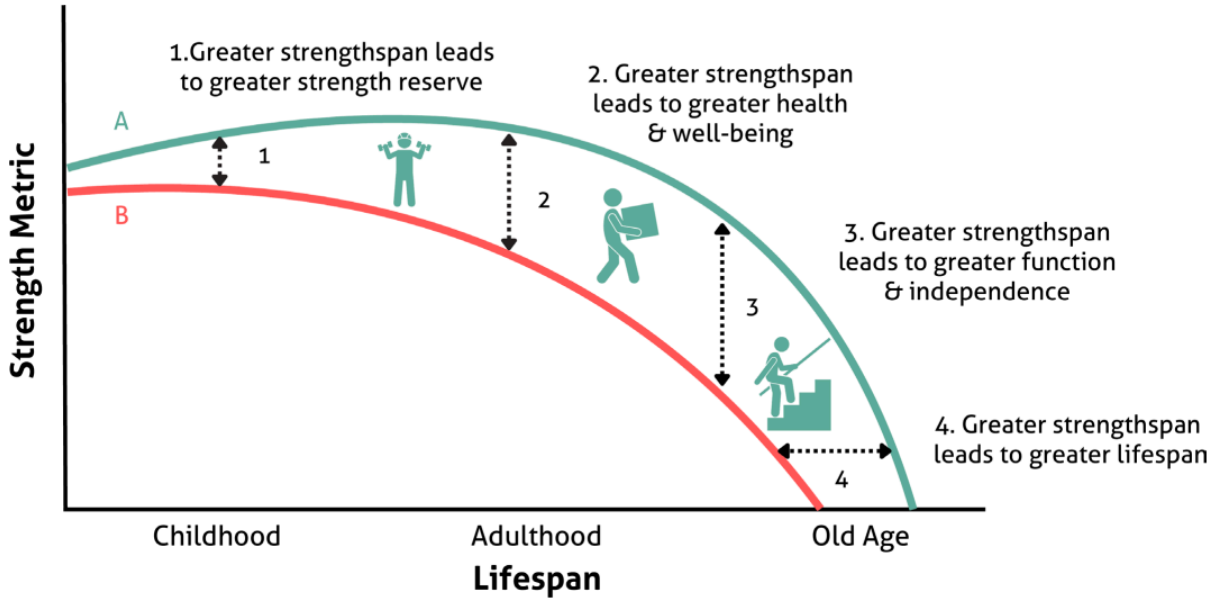
How our body composition affects our health

General opinion doesn't consider bodybuilding as a healthy activity, but bodybuilding's reputation for being unhealthy is mainly due to steroid abuse and psychological problems associated with competing at extremely low body fat levels. The essence of bodybuilding, being lean and muscular, is normally very good for your health.

Muscle mass

Muscle mass is not commonly thought of as a necessarily healthy tissue, but muscle mass is positively associated with various health biomarkers, disease risk, all-cause mortality and consequently longevity. More muscular people tend to live longer than less muscular people. Muscle strength is also a powerful predictor of mortality risk and quality of life [2, 3]. The most obvious health benefit of muscle mass and strength is protection against physical frailty [2], such as from falls. However, strength itself does not improve longevity. Strength is correlated with mortality primarily because it's a proxy for muscle mass. Most benefits of higher muscle mass seem to be mediated by improved insulin sensitivity. While it's difficult to separate the effects of exercise and muscle mass per se, higher muscle mass is generally positively related to insulin sensitivity and a lower risk of developing diabetes. Muscle mass is responsible for most of the blood sugar uptake after you eat, so it's crucial to keep your blood sugar levels in check. Deconditioned muscles suffer from mitochondrial dysfunction, impaired blood flow, fat build-up and inflammation, causing insulin resistance in the muscles and consequently in the rest of the body. Healthy muscles essentially function as a

sponge for blood glucose, thereby preventing hyperglycemia and reducing the demand for insulin production to keep blood sugar levels in check. Muscles also secrete myokines that can improve insulin sensitivity by regulating the activity of our pancreas and other organs. Insulin sensitivity in turn is correlated with systemic inflammation and thereby with a large array of health pathologies.



The relationship between muscle strength and the quality and quantity of life. Source

Fat mass

Fat tissue, especially the visceral fat around your organs, negatively influences many systems in the body [2]. Visceral fat mass secretes inflammatory proteins, hormones and other substances that decrease our insulin sensitivity, promote inflammation and disrupt our hormonal balance. Excess fatty acids can also accumulate in our blood vessels and other organs, impairing their functionality. Being lean protects against diabetes, reduces chronic inflammation levels and corrects hormonal imbalances [2], whereas obesity is causally related to virtually all leading causes of death and

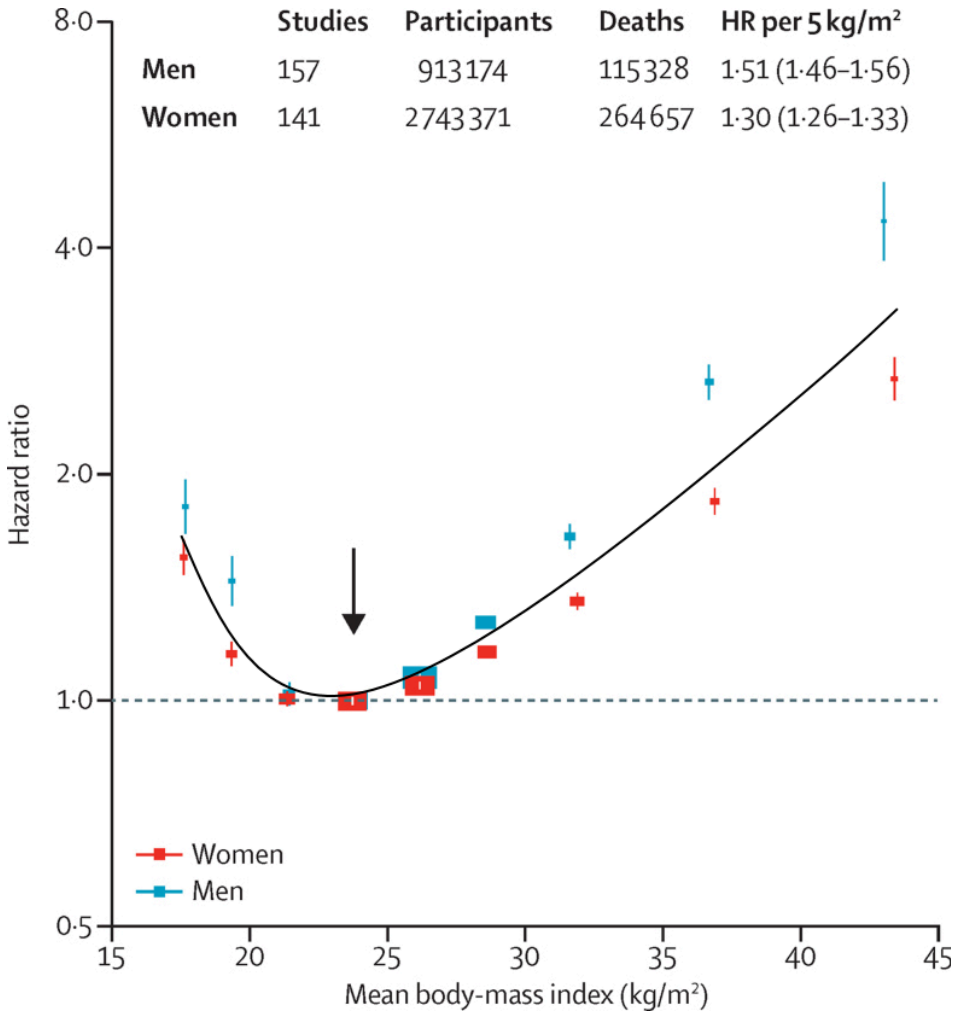
someone's waist-to-height ratio significantly predicts their mortality risk. In fact, being overweight is currently the second leading risk factor of preventable deaths in the modern world and is expected to take over tobacco use soon. Experiments show losing body fat has very strong and consistent positive effects on almost every health biomarker, including blood sugar, heart rate, cholesterol levels and systemic inflammation markers. Being in energy deficit also promotes autophagy, a cellular clean-up mechanism that recycles and removes excess and dysfunctional components of the body. A 2021 meta-analysis confirms weight loss improves health-related quality of life in overweight individuals, with greater effects in more obese individuals [2].

The rate of weight loss and even diet quality often do not matter as much for our health as the loss of body fat.

Energy restriction, or rather staying lean throughout your life, also increases the lifespan of various animals, including primates. Studies on humans have also found improvements in biomarkers of longevity and many health biomarkers, operating via similar mechanisms as in rodents, suggesting we too can live longer if we stay lean [2, 3, 4, 5, 6, 7, 8, 9]. Energy restriction decreases inflammation and oxidative damage, which can decrease the rate our DNA degrades over time. However, not all research in primates shows calorie restriction improves longevity, and since it's logistically and ethically infeasible to conduct life-long RCTs on humans until they die, we are limited to animal studies, epidemiological data, mechanistic evidence and RCTs up to 2 years in length. Centenarians – people that live over 100 years old – are rarely overweight and have been found to have a metabolic profile very similar to those of people in energy deficit. Calorie restriction is currently the most likely candidate to delay the health defects of age, with exercise being contender 2 mostly effective to manage the symptoms.

The health benefits of energy restriction are so profound that many researchers question if overweight individuals can even be perfectly healthy. Older research identified certain people that were overweight but seemingly healthy based on their current biomarkers. This led to the idea of 'healthy at every size'. However, many individuals who appeared to be 'metabolically healthy overweight' turned out to have considerable subclinical health problems. Moreover, when you follow these individuals over time, 'healthy overweight' individuals are also at greater risk than leaner individuals of developing metabolic risk factors and diseases [2, 3, 4, 5, 6]. Physical activity can only compensate for excess body fat up to a point [2]: it can address the symptoms but not address the root cause of the problems. One scientific review concluded that "obesity and metabolic dysfunction are inseparable and that healthy obesity is best viewed only as a state of relative health but not of absolute health." Other research has come to similar conclusions. Put bluntly, obesity has been called a timebomb by health researchers [2, 3].

In short, for optimal health, you need to be lean and at least somewhat muscular. As a result of those 2 opposing effects on our ideal bodyweight, meta-analyses find a J-shaped relationship between BMI and all-cause mortality [2], as illustrated below. People have the lowest risk of dying from any cause at a BMI of 20-25 compared to when they're underweight or overweight.



The relative risk of dying (all-cause mortality) in men and women based on their BMI. Adapted from the Global BMI Mortality Collaboration (2016).

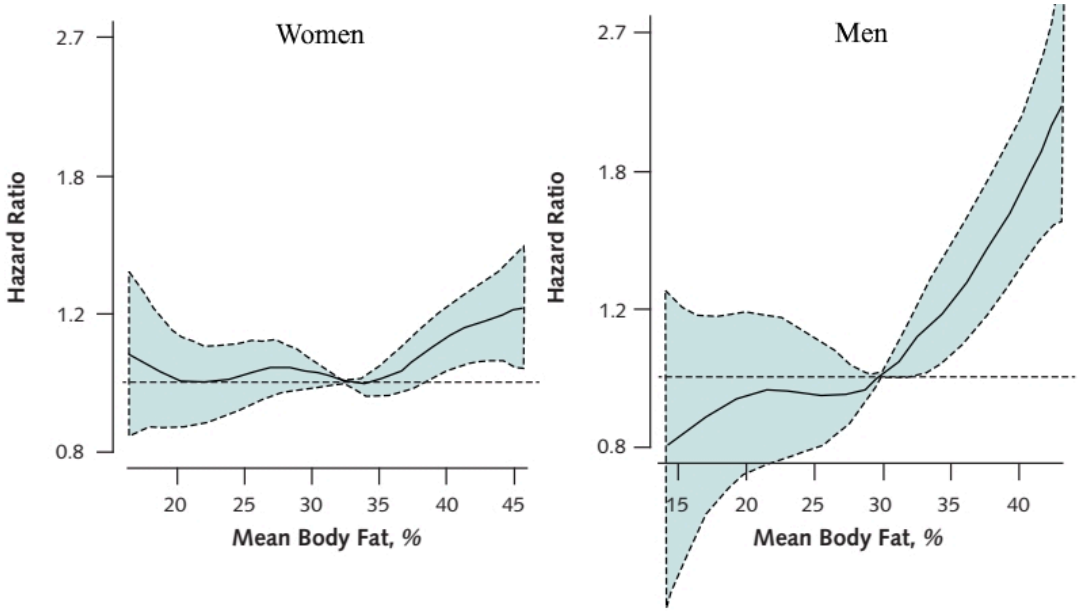
If a low body fat level is so healthy, why do we see higher mortality rates among underweight people? Researchers have found multiple reasons for this.

1. Smoking, certain diseases and certain infections tend to lower your bodyweight by lowering your appetite and/or causing muscle wasting (cachexia). They obviously

also increase your mortality risk. This causes a non-casual correlation between being underweight and mortality, a phenomenon called residual confounding.

2. Malnourishment. Malnutrition is associated with increased mortality risk, obviously, and the risk of nutritional deficiencies is obviously also higher in people that eat less. As you learned in the micronutrition module, most people's diets are so poor that they're at risk of multiple micronutrient deficiencies.

3. Being underweight is associated with low muscle mass. When correcting for the low muscle mass, most health risks from being underweight disappear [2]. Since BMI does not discriminate between lean mass and fat mass, and people with a high BMI typically have more lean mass than lower-weight individuals, the health benefits of muscle mass show up in BMI research as health benefits of a high BMI. See the following graphs adapted from Padwal et al. (2016), for example.



Relative risk of dying in fully adjusted models that included BMI and body fat percentage together.

Of course, there's more to life than not dying. Just because a body fat percentage is not associated with mortality, that doesn't mean it's optimally healthy. If we look at direct health biomarkers, such as insulin resistance or cholesterol levels, rather than death rates, many health benefits of energy restriction and fat loss continue without a clear limit. The leaner we get, the better these aspects of our health become. A recent 2022 review concluded obese and 'normal weight' individuals – a dubious term considering the majority of people in modern societies are overweight – achieve similar health benefits from losing fat: "the same degree of calorie restriction and the same amount of weight loss have multiple beneficial effects on health outcomes in individuals without obesity, similar to those observed in individuals with obesity." A 2022 meta-analysis found that weight loss also improves cognitive functioning, including global brain functioning and memory, even in non-overweight individuals.

So if you don't smoke, you're free from disease, you maintain your muscle mass and your diet quality is high, is there such a thing as an unhealthily low body fat level per se?

Yes, there is. For one, some body fat is essential to our survival. So called essential fat is required for the functioning of bone marrow, the central nervous system, internal organs, the cell membranes and, in women, the mammary glands and the pelvic region. Essential body fat stores comprise 3-5% of bodyweight for men and 8-12% for women. We can thus safely say those levels of body fat are unhealthy. "But Menno, this guy in my gym says he's at 2% body fat." Reality check: if you heard anyone boast about being that lean and they're not speaking to you from the afterlife, they're most likely misinformed. They probably used some crappy body fat caliper or BIA scale that's calibrated for sedentary individuals.

Based on the above data, we can say that our health likely takes a turn for the worse somewhere between 12-16% body fat for women and 5-13% for men. This estimate is supported by studies on physique contest competitors, such as bodybuilders. Studies that follow physique competitors find that when they get even leaner than sixpack lean, their natural anabolic hormone production decreases. Men may even develop hypogonadism as their gonads stop producing healthy levels of testosterone. Women may lose their menstrual cycle (amenorrhea), with well-established adverse effects on fertility and health.

Research has also found that intensive exercise combined with prolonged energy deficits to cut to very low body fat levels suppresses our immune system [2] and may cause inflammation. However, the negative effects of dieting to very lean levels may be the result of insufficient micronutrient and anti-oxidant intake, which were explicitly diagnosed in one study, not necessarily their low body fat level. In other research, contest prep in female physique athletes who were already in great health still decreases inflammation levels and further improves cardiometabolic health. Most common health markers, such as insulin sensitivity, heart rate and cholesterol levels, typically keep improving even when approaching starvation-level body fat stores.

Third, the stress of trying to maintain an unsustainably low body fat level may start affecting your physical health. Physique contest competitors typically experience elevated cortisol levels and disrupted mood states. Mental health correlates with physical health. The healthier people are, the happier they tend to be. Being metabolically unhealthy is associated with a 19-60% increased risk of depression; if you're also obese, the added risk increases to 30-83%. Mental stress is not just a killjoy but also effectively an off-switch for reproduction, growth, repair and digestion. That's not a good state to be in long term.

Fortunately, any negative effects of being contest lean are temporary. Even women that completely lose their menstrual cycle during prep fully recover their hormonal health during a subsequent bulking phase [2] and our immune systems also fully recover.

In sum, muscle mass seems to be inherently beneficial for your health with no known side-effects. Fat mass is generally detrimental: the lower your body fat level, the better most of your health biomarkers – insulin sensitivity, cholesterol levels, heart rate, etc. – tend to be. Being underweight is mostly a problem related to low muscle mass, not low fat mass. However, when you get to generally psychologically unsustainable body fat levels, such as for a physique contest, you may experience transient negative health effects. As a rule of thumb, the lowest sustainable body fat level for women is the level at which they can maintain their regular menstrual cycle, assuming they had one in the first place. This should be roughly in the range of 15-20% body fat. Higher body fat levels in women are generally not a health problem until at least 25% though. Men should generally avoid spending prolonged periods of time below 10% body fat. A visible sixpack should be realistic, but keep an eye on your mental health and libido when dieting to even lower levels. There should be no serious health issues in men up to at least 15% body fat.

Health effects of exercise

Most people know endurance exercise is good for your health, but strength training also confers many of the same health benefits as endurance training, such as reducing chronic inflammation and improving cardiovascular health [2, 3, 4] and strength training is associated with considerably lower all-cause mortality, independent of aerobic exercise [2, 3]. If you logically think about it, any form of physical activity confers a degree of aerobic exercise benefits, as it will elevate your heart rate and increase oxygen usage.

Strength training also has numerous cognitive benefits, especially in elderly populations, by virtue of reducing neuro-inflammation and improving the secretion of brain-derived neurotrophic factors. Since systemic inflammation can damage pretty much everything in the body, maintaining low inflammation levels is strongly associated with quality of life. A 2023 meta-analysis found that strength training and endurance training both significantly improve how well our brains function. All cognitive domains improved with exercise, including global cognition, executive function, memory, attention and information processing. The effects were strongest in older individuals but also present in healthy adults and children.

The effect of exercise, including strength training, on wellbeing is also very positive, often larger than going from a yearly income of $15k to $50k. Strength training also benefits your psychological health in several different ways, regardless of your age or gender [1, 2, 3, 4, 5, 6].

- Strength training increases subjective wellbeing and positive mood state and decreases depression.
- Strength training decreases your stress levels, anxiety and neuroticism.

- Strength training improves your self-esteem, self-satisfaction, body image and self-concept.
- Specifically relevant for the ladies: strength training makes premenstrual syndrome more tolerable.

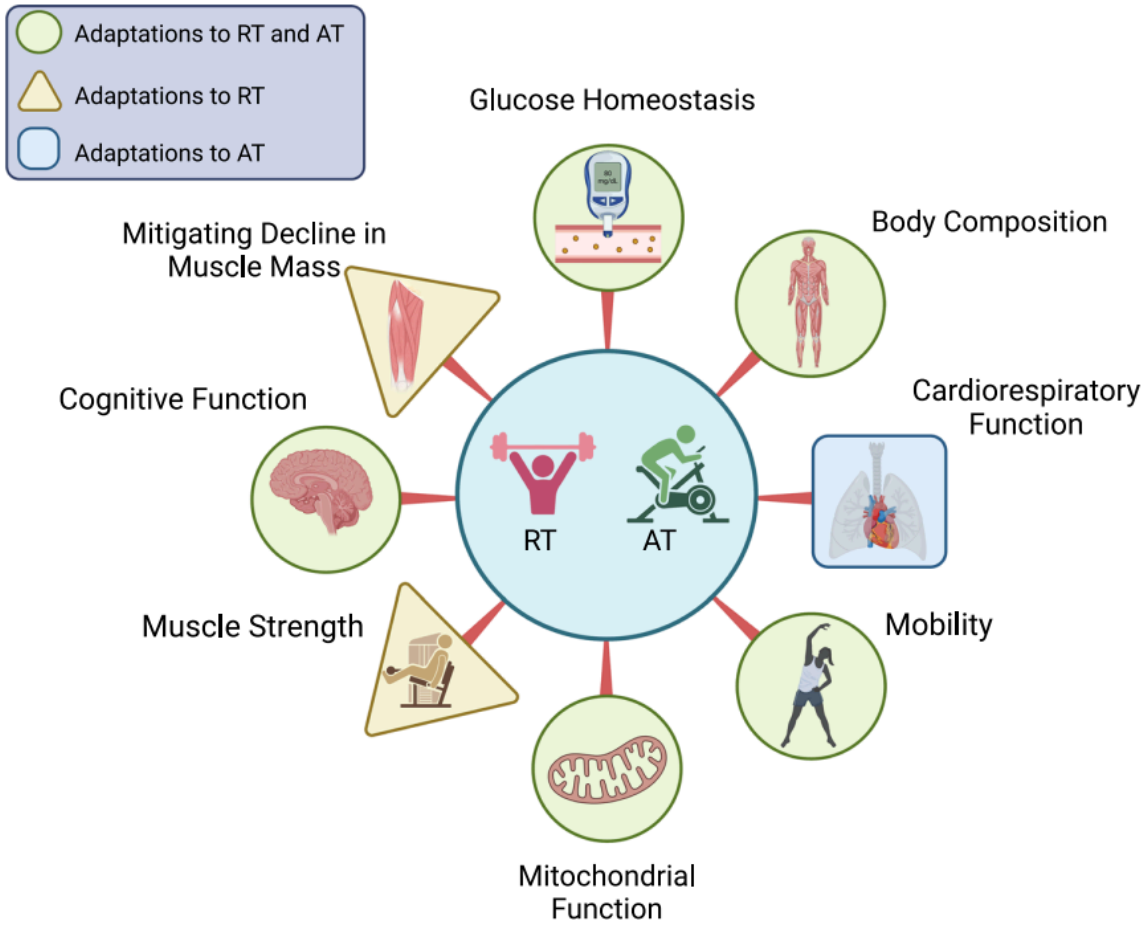
Bodybuilding type training is particularly healthy for diabetics. The combination of rapid fat loss, muscle growth and high-volume exercise is so effective to improve insulin sensitivity that it can effectively cure type II diabetes in as little as 8 weeks. Lean, muscular, strength training individuals have practically no chance of becoming diabetic, unless they have a major genetic predisposition.

Higher strength training volumes generally lead to greater health improvements than lower volumes. A 2023 meta-analysis found around 77 total sets per week led to greater health improvements, in particular for glucose control and inflammation, than 44 sets per week. A study by Nunes et al. (2016) found greater health improvements with 144 total weekly sets than 72 sets.

For *optimal* health, you probably need to do both cardio and strength training, as they provide different health benefits to some degree. In support of this, a 2018 meta-analysis and a large-scale 2022 prospective analysis found that individuals who adhered to both strength and endurance training official physical activity guidelines had lower all-cause mortality than people who adhered to only either or neither one. Similar findings have been reported for cancer mortality.

However, research finds clear ceiling effects (upper limits) of exercise's health benefits: you can only get so healthy. For example, having high blood pressure poses significant cardiovascular health risks, but once your blood pressure is in the ideal range, there's no point in lowering it further. Most research finds the health benefits of exercise

plateau after a couple hours per week [2, 3, 4, 5] or in some odd cases even just a single hour, and endurance training in particular even backfires when you start doing very high training volumes [2, 3, 4], like ultra-marathons.



The health benefits of aerobic training (AT) and resistance training (RT): there's large overlap, but RT is more effective against sarcopenia while AT is more effective to improve cardiorespiratory functioning. Source

Non-exercise physical activity

Your overall physical activity level outside of exercise can also affect your health, even independently of exercise. A 2024 systematic review found that sedentary time and physical activity level had partly independent relations to cardiovascular disease risk. High physical activity levels could only compensate for being highly sedentary up to a point. Breaking up sedentary time may be especially important to avoid the negative effects of being highly sedentary. In the same way that exercise improves blood flow and overall metabolic activity, being sedentary decreases metabolic activity. You can think of your body's health as the cleanliness of a lake's water: swirling the water around vigorously for an hour is great, but if the water's completely still the rest of the time, it may still not be perfectly clear.

A decent measure of someone's overall non-exercise physical activity level is their daily step count. The principle of diminishing returns likely also applies to your daily physical activity level, but the data on step counts are conflicting. A 2022 meta-analysis of cohort studies found that all-cause mortality plateaued after a daily step count of about 8000 steps in adults; however, for elderly individuals above 60 years old, higher step counts were associated with better health. These findings align with a 2023 meta-analysis's conclusion that the optimal step count for health is on average 8.8k steps a day. In contrast, another 2023 meta-analysis found that the higher the step-count, the lower the all-cause mortality for all age categories. Why do different studies come to different conclusions? Step counts are a crude measure of one's physical activity level, let alone one's health, for multiple reasons. These associative analyses merely show correlations, not causations, and they are plagued by many statistical problems, such as reverse causality (health problems may reduce activity levels rather than the other way around), residual confounding (other factors, such as genetics or happiness, may improve both health and activity levels) and the presence

of multiple covariates (step counts may serve as a proxy for a generally healthy lifestyle or exercise level, while step counts per se may not be that important).

In support of a plateau in health benefits of high physical activity levels, a 5-year RCT study on older adults by Stensvold et al. (2020) found no significant effect of adding 2 days of either moderate-intensity cardio or high-intensity interval training (HIIT) on all-cause mortality in subjects who were already moderately active for at least 30 minutes a day. Epidemiological research also supports that the total weekly volume of physical activity is more important than the intensity and frequency: high step counts can reduce all-cause mortality and hypertension as much as endurance training [2]. Endurance training is very time-efficient for health benefits, but you can compensate for lack of endurance training with a higher step count to a large extent, especially if you already do strength training. Strength training provides a decent level of cardiovascular fitness too, in particular if you do full-body workouts with combo sets and moderate-to-higher reps [2, 3, 4].

So when you take an individual who already has a healthy diet, they're lean, they're muscular, and they engage in strength training several times per week, will adding cardio or increasing their daily step count make them healthier? There's scant research on this, but the effect will likely not be large, especially when we consider that for most people, all forms of physical exercise compete for the same time we have. As you'll learn in the cardio module, for the first few hours of exercise, strength training offers greater health benefits than cardio per minute of exercise, primarily due to its greater positive effects on our body composition. Adding cardio to strength training should improve cardiorespiratory health outcomes due to the difference in adaptations. A high step count will not elevate your cardiorespiratory fitness, such as your VO2 max, nearly as much as dedicated endurance training. Breaking up sedentary time is also likely

beneficial to some degree, but the overall step count at this point may not matter much anymore.

In sum, for absolutely perfect health, you'll likely need to perform some volume of strength training, endurance training and general daily physical activity. However, your total weekly volume of physical activity is likely most important, with higher-intensity exercise counting more than lower-intensity physical activity. Moreover, there are strong diminishing returns to higher volumes of physical activity with most benefits being obtained in the first few hours per week. Concrete aerobic exercise guidelines will be discussed in the course module on cardio.

Sauna bathing

Emerging evidence is supporting significant health benefits of sauna bathing – yes, sitting in a hot sauna. The sauna is typically seen as a way to relax, and part of the health benefits likely result from its use as a stress-reducing leisure activity, but the sauna also stimulates significant physiological adaptations. Sauna often have an ambient temperature of 40-100°C with dry (Finnish) saunas on the upper end of that and wet, steamy saunas on the lower end, as humidity increases the effects of the temperature. These conditions induce mild hyperthermia – overheating – in the body, triggering a thermoregulatory heat stress response with blood pressure-reducing, anti-inflammatory, antioxidant, cytoprotective, and stress-reducing effects. Just like exercise, this type of stress is hermetic: it stimulates positive adaptations to adapt to the stress and maintain homeostasis ('regular bodily functioning'). A 2018 systematic review concluded the adaptations to (dry) sauna bathing are generally positive for our health. Most of the adaptations are in the vascular system. A 2021 meta-analysis found that regular sauna bathing lowers systolic and diastolic blood pressure by a clinically meaningful 4 mmHg in sedentary individuals.

Sauna use is associated with a wide variety of health benefits in cross-sectional studies as well, in particular vascular improvements, including in fit individuals but primarily in unhealthy populations. Importantly, the observational research is limited by sauna bathers differing from the general population in multiple key ways that may exaggerate the benefits, such as more leisure time, higher socioeconomic status and greater health-consciousness. However, socioeconomic status only seems to partly explain the health associations of sauna usage.

Arguably the most compelling evidence of the sauna's health benefits for lifters is a 2022 RCT by Lee et al. Compared to concurrent exercise alone, the addition of 15

minutes of post-workout Finnish sauna bathing considerably augmented the improvements in VO_2 max, systolic blood pressure (-**8** mmHg) and total cholesterol levels. The participants were super sedentary with at least one risk factor for cardiovascular disease and the training programs were not that intensive: 20 minutes of circuit resistance training followed by 30 minutes of steady-state cardio. It's questionable if fitter individuals would experience similar benefits. Saunas can significantly elevate heart rates, which may cause positive cardiovascular adaptations in untrained individuals, but trained individuals are less likely to experience further such adaptations. However, associative studies have found that sauna usage frequency is still associated with health benefits in individuals with above-average cardiorespiratory fitness. Moreover, a 2008 RCT by Scoon et al. found that regular post-workout sauna bathing improved competitive runners' times by ~2%, suggesting even very fit individuals can still experience health benefits from the sauna. However, a notable limitation of both of the above RCTs and much of the sauna research in general is the lack of an appropriate placebo-control. Most control groups receive no intervention instead of a sham intervention.

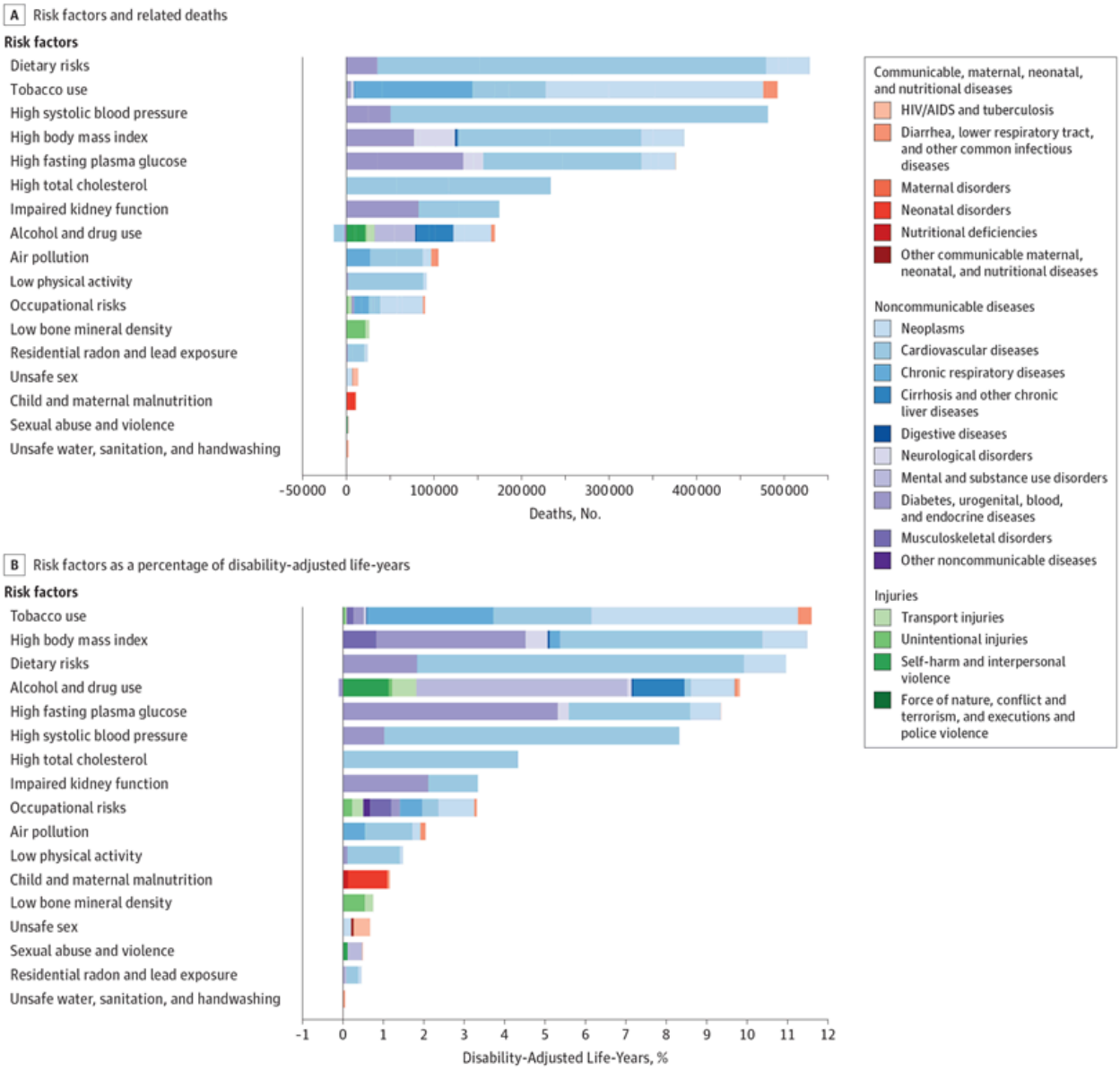
In one of the few studies on sauna use by elite athletes with a placebo-control, post-workout sauna bathing **worsened** swimming performance the next day. Athletes should thus beware that sauna bathing with significant heat stress may prolong recovery times.

Sauna bathing is also not completely free from side-effects. While it's generally safe, sauna use can result in "a strong impairment of sperm count and motility" even with just 2 weekly sessions in a Finnish sauna. Heat is well established to be toxic to sperm. Even high ambient temperatures decrease sperm quality. The reduction in sperm quality seems to be completely reversible without any permanent damage, but it's probably prudent for men to avoid the sauna when trying to have kids.

On a final note, much of the research comes from Finland and the Fins are very proud of Finnish sauna bathing, so some (subconscious) research bias is plausible.

Diet quality: macros vs. food choices

In fitness circles, many people focus primarily on the macronutrient intakes of their diets and there's an everlasting high vs. low carb debate. For our health, however, our macronutrient intakes per se are not very important. What matters is which *foods* we consume, not which macronutrients they have. The ratio of carbs to fats in our diet has little relation with our health, but overall diet quality does [2, 3, 4, 5, 6]. The quality of the foods we eat is monumentally important. Diet quality is the number one predictor of early death and roughly tied with tobacco use as the number one predictor of poor health in the US, even independent of BMI(!): see the graph below. If you add the predictive power of BMI and diet quality together, the resulting health benefits massively overshadow any other factor.



[Source]

Dietary inflammation index

One promising way to rank foods in terms of healthiness is the diet's inflammation index. Inflammation is a key commonality of many disease states. Inflammation signals your immune system to pay attention to an area, so inflammation itself is not a bad thing. It's in fact part of the body's healing process. However, inflammation is often a

response to something harmful for the body, in particular tissue damage or a harmful substance in the body. When the body registers the presence of harmful pathogens like bacteria, fungi or viruses, it can send white blood cells to neutralize the pro-inflammatory pathogens. For example, lymphocytes are key parts of the immune response to deal with viruses. Lymphocytes include natural killer cells, T cells and B cells.

When someone is in poor health, they often develop systemic inflammation: persistently high inflammation levels throughout the body. This essentially means that the immune system is trying to put out fires all across the body: there are problems everywhere. Since systemic inflammation correlates with overall poor health, we can get a reasonable idea of how healthy foods are based on how inflammatory or anti-inflammatory they are. Broadly speaking, all sources of energy have inflammatory potential, because the production of ATP in our mitochondria forms reactive oxygen species (ROS), a type of reactive species formed during oxidation. ROS are free radicals that 'miss' an electron – technically, they have an unpaired valence electron – which causes them to be highly unstable and to absorb the electrons of other compounds to stabilize themselves, destabilizing the other compound in the process. In a healthy state, free radicals are kept in check by anti-oxidants, but in large numbers they can cause oxidative stress and inflammation. ROS can damage DNA, proteins and lipids in the body, causing a wide variety of problems. A food's anti-inflammatory potential is thus achieved primarily through its anti-oxidant content relative to its energy density. The chief anti-inflammatory components of food are fiber, omega-3 fatty acids, vitamins and phytochemicals such as flavonoids.

The Dietary Inflammation Index (DII) is arguably the current best attempt to estimate how inflammatory a certain food or diet is based on its components. Someone's DII significantly predicts their all-cause mortality. The top tier of anti-inflammatory foods

consists mostly of herbs and vegetables. The exact ordering of foods remains contentious, however, as there are multiple inflammation indices in use and a lot of research still relies on correlations between diets and systemic inflammation levels rather than causative mechanisms.

So let's discuss which specific food groups are best for our health. We'll focus on whole foods, as highly processed foods are almost invariably bad for our health without offering any health benefits in return. Generally speaking, the further you process something that grows or lives in nature, the more nutrients and beneficial compounds it loses, and the more inflammatory it becomes.

Food choices for optimal health

Water

Water is often called the most important nutrient. It's the only nutrient we can't do without for even a few days. Dehydration of over 7% of bodyweight puts you at acute risk of dying, although you generally don't die until you're 15-25% dehydrated. It's not surprising then that milder dehydration can already impair your performance in the gym. So the traditional advice is to drink a ton of water during your workouts. A gallon (3.8 L) is commonly heard. Let's look at how much water we need to function optimally.

Health

Nutritionists commonly recommend us to consume at least 8 cups of 8 ounces of water a day, amounting to 1.9 L of water, not factoring in the extra requirements due to exercise. Some recommend much more. The United States Department of Agriculture (USDA) long recommended 13 cups for men (3.7 L) and 9 cups (2.7 L) for women. However, the widespread 8x8 recommendation has never been grounded in any solid scientific data, let alone the higher values.

First, it makes no sense to have a recommendation for drinking water intake specifically. The body is very good at absorbing liquids from all kinds of beverages, as well as from food moisture. Many whole foods have a high moisture content, a primary reason for their low energy density compared to more processed foods. Thus, modern scientists generally recommend a certain total water intake from all sources rather than a fluid intake specifically. The evidence-based total water intake recommendation according to a review by the European Food Safety Authority (EFSA) is 2.5 L for men and 2 L for women under mostly sedentary, regular living conditions.

Even this recommendation may be redundant. A 2021 meta-analysis found no significant difference in all-cause mortality between high and low total or drinking water intakes. They did find evidence of non-linearity with possible health benefits for cardiovascular disease mortality at low water intakes. The lack of clear association between water intake and health is likely due to people's high variance in water requirements and our innate ability to drink enough to suit our individual requirements based on our thirst. The body regulates its own hydration level very well. Dehydration will increase plasma osmolality, which is the concentration of solutes in our blood plasma. In other words, plasma osmolality is a measure of our water-electrolyte balance. Any dehydration resulting in a rise in plasma osmolality of less than 2% will make us thirsty, whereas dehydration typically requires a rise over 5%. Thus, our sense of thirst normally autoregulate our hydration level and achieves homeostasis around a relatively narrow equilibrium point. We get thirsty well before we develop fluid losses or show signs of objective dehydration: our thirst is not just compensatory but also anticipatory. In case you heard that 'thirst is too late', this is simply a myth.

You can roughly tell how hydrated you are based on the color of your urine. The darker your urine, the more concentrated it is and the less hydrated you are. Dehydration will thus make your urine darker. At normal hydration levels, your urine is up to moderately yellow. It doesn't have to be pale yellow or clear like water, but it should not be dark yellow or brownish.

Just drinking based on thirst and preventing clear dehydration is probably enough for most people to be very healthy, but for optimal health, it may be beneficial to make water or other drinks easily available for yourself. Evidence from randomized controlled trials does suggest potential benefits of higher water intakes for various health outcomes, even if they don't seem to affect mortality. However, the evidence is very mixed, confounded by weight loss and of generally low quality.

Physical performance

While fluid intake recommendations are often given for ‘exercise’ as a general group, it’s mainly endurance exercise that suffers from water losses according to a multitude of studies.

- 2.5% of bodyweight dehydration from playing baseball in the sun did not reduce anaerobic power output.
- Progressive dehydration by jogging in the heat only affects isokinetic leg extension strength after 2.6% of bodyweight dehydration. Vertical jump performance, muscle activation and more rapid isokinetic leg extension strength weren’t affected by even 3.9% dehydration. However, isometric leg extension strength was already affected after 1% dehydration.
- 3.4% dehydration from a sauna impaired isometric leg extension strength, but 3.8% dehydration from using a diuretic did not.
- 4% hypohydration from hours of exercise in a warm room did not generally affect muscle strength.
- 2+% dehydration caused no change in muscle activation or motor control of the biceps.
- 2.3% of dehydration did not impair repeated maximal cycling power output in boxers.
- 5% dehydration by exercise-heat stress and fluid restriction did not affect vertical jump height, jump squat power output or isometric back squat strength in strength trained men. However, after 2.5% dehydration, central neural drive was impaired and total work across 6 sets of back squats at 80% of 1RM

suffered in 2 of the sets (4 after 5% dehydration).

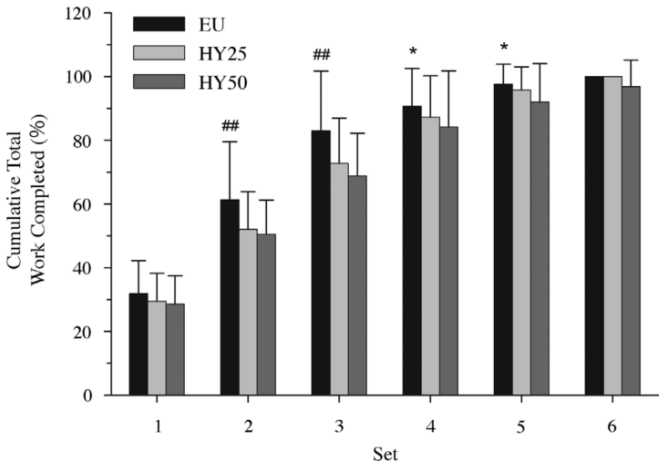


FIGURE 2—Cumulative total work completed (mean ± SD) after each set during the REC (for description of this calculation, please see Methods). EU, euhydrated; HY25, hypohydrated by approximately 2.5%; HY50, hypohydrated by approximately 5.0%. ## Significant difference between EU and both hypohydrated trials; * significant difference between EU and HY50.

- 1.5% dehydration from spending 2 hours in a sauna decreased 1RM bench press strength. However, letting the subjects consume water ad libitum for 2 hours after the sauna undid the performance loss.
- 3% dehydration reduced total work by ~1-2 reps per exercise during a strength training workout of 3 sets each of the bench press, lat pull down, overhead press, barbell curl, triceps press and leg press until failure. Heart rate increased as well and there was a weak trend for an increase in perceived exertion (RPE; interestingly, a case when physical performance was significantly impaired but RPE was not).
- 3% dehydration did not affect repetition performance or ratings of perceived exertion (RPE) of 5 sets of bench presses and leg presses to failure at 75% of 1RM in strength-trained women. The women did report lower perceived recovery status and readiness to perform, indicating they were mentally affected by the dehydration before their performance was objectively affected.
- 1.5% dehydration did not affect 30-second all-out sprint performance (Wingate test) or jump height.

Overall, the effects of dehydration are mild enough that it's often objectively worth it for athletes to cut water before a competition. Many combat sports medal winners undergo marked dehydration before the weigh-in, which isn't fully reversed yet at competition time. In general, the more explosive the type of exercise, the less it suffers from dehydration. Exercise of 15 seconds or less in duration generally doesn't suffer from dehydration at all. Dehydration only consistently impairs exercise lasting more than 30 seconds per bout. Strength training performance is generally not affected up to 2.5% of bodyweight dehydration. That's 2 kg (4.4 lb) of weight loss from hypohydration for someone weighing 80 kg (176 lb), a far cry from "I'm a bit thirsty." Even 3-4% dehydration leads to only a 2% average loss in strength.

Interestingly, dehydration may have a more negative effect on the upper than the lower body, as illustrated below.

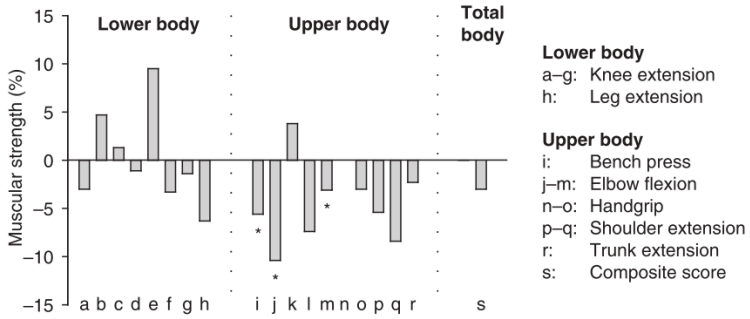


Fig. 1. Non-confounded effects of hypohydration on muscular strength. Data are presented as mean percentage change from baseline. Results from: Bosco et al.[50] (a, h, j, n, o, r and s) [estimated from figures]; Greiwe et al.[34] (b and k); Viitasalo et al.[52] (c); Bosco et al.[81] (d, e, l, m, p and q); Bigard et al.[82] (f and g); and Schoffstall et al.[40] (i). * $p < 0.05$.

Source

Hormonal responses are in line with performance during dehydration. 5% dehydration significantly reduces testosterone secretion after strength training and increases cortisol and norepinephrine levels but 2.5% dehydration did not, though there was a trend for similar negative effects.

Cognitive performance

Before your physical performance starts to suffer, you may mentally already *feel* worse. Mental performance generally starts deteriorating before our physical performance does. Dehydration can already impair cognition at water losses of 1-2% of bodyweight [2]. However, just like for physical performance, it generally takes dehydration levels above 2.5% of bodyweight before our performance on objective mental tests consistently suffers [2, 3, 4, 5]. It typically requires heat stress, diuretics or physical exercise to affect our mental state or cognition with dehydration. After stress-induced dehydration, it's debatable to what extent cognitive performance is impaired by dehydration per se compared to the stress, fatigue and unpleasantness.

So how much water do you need?

In contrast to popular belief, the level of dehydration that impairs physical performance or your health won't commonly occur unless you're intentionally restricting your fluid intake. Even during long endurance events, like marathons, there is generally no advantage for performance to drink more than you would based on your thirst, as shown by a 2019 meta-analysis. Several studies have found that drinking 2-3.5 times as much did not improve race times even in considerable heat.

In conclusion, unless you're going out of your way to dehydrate yourself by actively limiting fluid intake, exercising in the heat, spending hours in a sauna or consuming diuretics, dehydration most likely isn't going to impact your strength training or your health. For workouts of fewer than 90 minutes in particular, drinking to thirst generally suffices to stay adequately hydrated.

Drinking too much can even be harmful. Overhydration can cause hyponatremia, a condition with low sodium levels in the blood and accumulation of fluid.

Exercises-associated hyponatremia (EAH) has caused death in several cases among endurance athletes, the military and the police. EAH arises when excessive fluid intake exceeds the fluid volume that you lose through sweating, respiration, renal excretion and feces. Mild symptoms include nausea, headaches, and lethargy, whilst more severe symptoms include edema, seizures, and loss of consciousness. Consumption of sodium during exercise doesn't solve this problem. In fact, extreme sodium intake may foster the overconsumption of water and increase the risk for EAH.

Hyponatremia is much more common than you may think. The prevalence varies from 8-50% for endurance athletes and strength trainees are at a greatly increased risk. Compared to endurance exercise, strength training results in little fluid loss (~1 L per hour) and a lot of sodium loss (> 1 g per hour) via your sweat, causing a decrease in blood sodium levels. Endurance exercise doesn't normally have this effect. Most strength athletes instinctively overhydrate during strength training by an overage of 96% (e.g. drinking 1.96 L of water during a workout where you only lose 1 L) and post-workout hyponatremia has been observed in up to 50% of American football and rugby players.

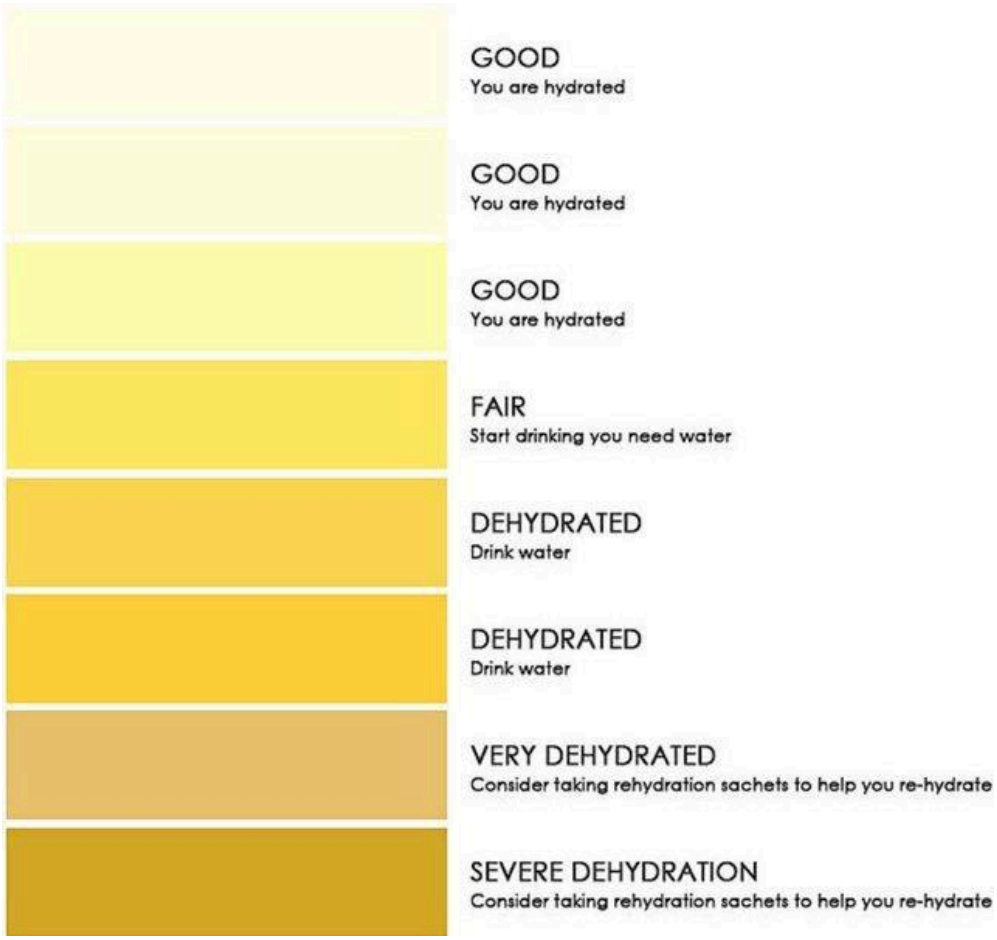
Several researchers have raised concern about the widespread endorsement to drink tons of water and its likely risk of overhydration.

So how much fluid should you consume in a day to avoid the negative effects from both dehydration and overhydration? What's the optimum fluid intake? There is little standardization across health institutes when it comes to water intake recommendations. While many organizations recommend very high water intakes that few people reach in practice, many other health organizations don't have a formal water intake recommendation at all. Few recommendations are directly supported by scientific research.

The practical answer is probably simple though. Due to water's essentiality, we have evolved a natural ability to ensure we drink enough water. The experience of thirst is a very effective feedback-controlled mechanism that regulates our fluid intake to avoid dehydration. Small changes in the solute content in the human blood stream trigger the sensation of thirst. Plus, trained individuals naturally become thirstier than untrained individuals in a hypo-hydrated state. As such, drinking in response to your thirst is often the best way to prevent dehydration and overhydration at the same time.

It's possible that increasing your fluid intake above intuitive levels confers some benefits for our health or wellbeing, even if it doesn't typically affect our physical or cognitive performance. However, any scant RCT evidence for above-habitual water consumption is almost exclusively limited to unhealthy populations. Spigt et al. (2006) conducted a 6-month RCT intervention in healthy, older adults. A 1 L per day increase in water intake had no effect on blood pressure, kidney functioning or quality of life. Moreover, habitual water intake is not consistently associated with all-cause mortality [2]. Nevertheless, very low habitual water intakes may be insufficient for optimal wellbeing. Pross et al. (2014) found that in people with a habitual water intake of only 0.7 L per day, increasing this to 2.5 L per day resulted in an overall improvement in their mood state.

You can verify you're amply hydrated by the color of your urine using the chart below. The more hydrated you are, the more water goes into your urine and the lighter in color it becomes. Your urine should generally be yellow. If it's completely indistinguishable from water, you may be overhydrated. If it's orange or brown, you may be dehydrated.



Exercising in a very cold climate and being elderly are associated with a decreased responsiveness to thirst, so these cases may warrant drinking a bit more than your thirst naturally makes you, although evidence for this is limited.

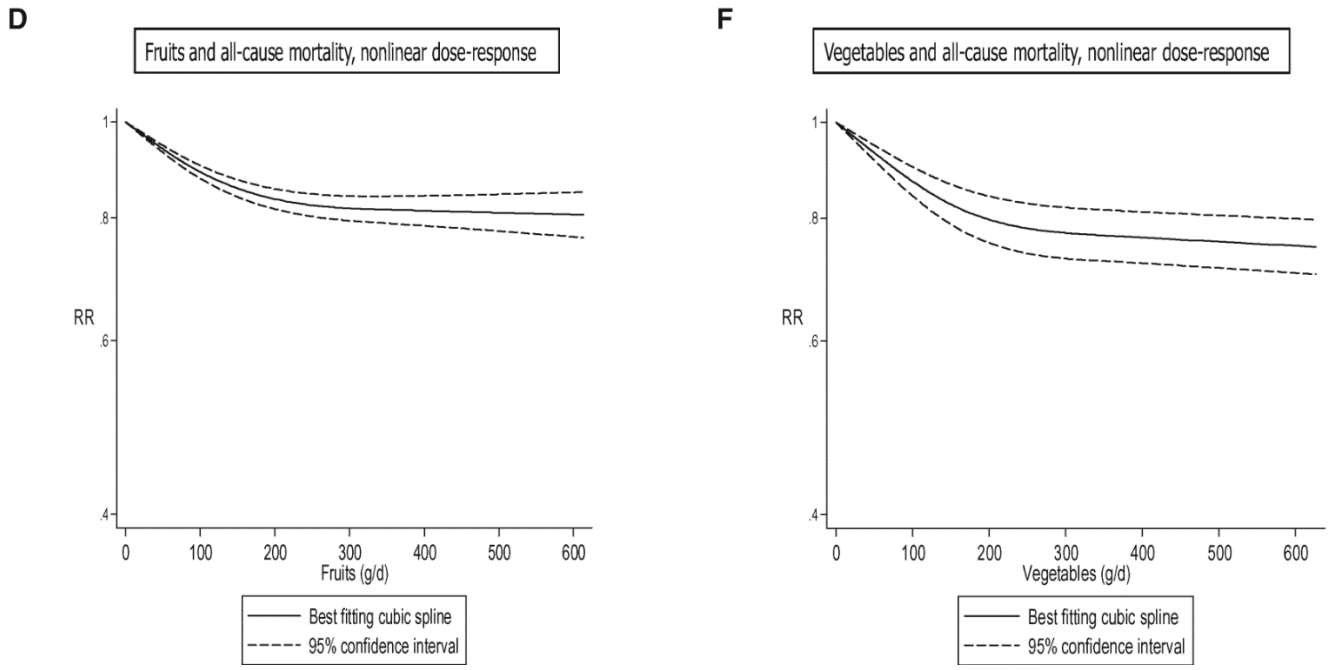
Fruit & vegetables

You may not want to hear it, but it's the only advice in the world practically every nutritionist agrees on: fruit and vegetables in particular are very healthy and should form the basis of your diet [2, 3, 4, 5, 6, 7, 8, 9]. Vegetables absolutely dominate all other food categories when it comes to nutrient density and fiber intake per calorie. Fruits and vegetables are also highly anti-inflammatory. On top of that, they're loaded with phytochemicals of which we're still constantly learning new health benefits.

Even psychological wellbeing is directly correlated with fruit and vegetable consumption [2], even after adjusting for many confounders, such as BMI, energy intake and socioeconomic status. Moreover, fruit and vegetable consumption can increase wellbeing acutely.

A lack of fruits and veggies is a primary reason many strength trainees are not nearly as healthy as they think. The USDA recommends that the average male consumes 3 cups of vegetables a day and 2 cups of fruit. For women it's 2.5 cups of vegetables and 1.5 - 2 cups of fruit. That's better seen as an absolute *minimum* for a strength training individual striving for optimal health. While short-term studies don't find major effects of fruit or veggie intake on health biomarkers, meta-analyses find benefits of up to 300 g of fruit and vegetables to reduce the risk of practically all major diseases and all-cause mortality. The latest meta-analysis found the benefits continue up to at least 800 g for all-cause mortality (see figure below). The combined intake of fruits and vegetables seems to follow the same dose-response as that of fruits and vegetables separately, suggesting they are largely interchangeable and have similar, overlapping health benefits. These data are in sedentary individuals; strength training increases many micronutrient requirements by around ~20%, as you learned in the module on

micronutrition. Therefore, strength trainees should ideally aim for around a kilogram of combined fruits and vegetables per day.



Up to 300 g per day of fruit or vegetables, all-cause mortality decreases significantly and considerably. After that, small benefits seem to continue up to at least 800 g per day. Source

Red meat

Red meat generally refers to the muscle tissue of mammals, including beef, veal, pork, lamb, mutton, horse, and goat. Red meat is a highly nutrient dense food with easily digestible nutrients and high-quality protein. Red meat is arguably the best source of l-carnitine, creatine and iron in the human diet and it's not too far off for vitamin B12.

Despite its nutritional value, red meat has garnered a reputation as being unhealthy. This reputation is in large part based on the saturated fat and cholesterol content of red meat. However, as you've learned in the course module on dietary fat, saturated fat and cholesterol from whole-food animal foods are not inherently unhealthy in the context of an overall healthy diet. Ironically, red meat doesn't even have that much saturated fat to begin with. Grass-fed beef is roughly equal parts saturated and unsaturated fat. Pork's fatty acid profile is even predominantly unsaturated, as is the fatty acid profile of chicken. These vindications have led many low-carb proponents to conclude red meat is very healthy.

Unfortunately, red meat has multiple other compounds with potential damaging effects on human health, especially if the meat was exposed to high heat. Red meat becomes unhealthy when you process it with certain chemicals, notably nitrates and nitrites. Nitrates and nitrites interact with substances in meat to form N-Nitroso-Compounds (NOCs) and nitrosamines in the human body, both of which are carcinogenic. NOCs are carcinogenic mutagens: they can damage human DNA and thereby cause cancer formation. Processed red meat consumption has been linked to cancer risk, in particular colon cancer, but also possibly breast, prostate, lung, rectal, bladder, kidney, pancreatic, ovarian, liver, esophageal and gastric [2] cancer. Most smoked, cured, fermented, salted and dried meat, like sausages, bacon and chorizo [2] have these effects.

Nitrate/nitrite-induced cancer risk may be mitigated by consuming anti-oxidants, such as green vegetables or vitamin C [3, 4]. Anti-oxidants and certain micro-nutrients, such as calcium, may also bind with NOC, rendering it harmless. Natural sources of nitrates and nitrites from plants do not seem to be harmful but actually healthy [2].

High temperature processing of red meat, in particular barbecuing or grilling over an open flame, may also increase our risk of cancer. Fat drippings can form polycyclic aromatic hydrocarbons (PAHs) at high temperatures [2]. PAHs are carcinogenic and toxic. If there is a lot of smoke and fat dripping out of the meat, this signals a high risk for PAH formation. Regular pan frying or boiling of meat does not seem to be very problematic.

Charcoaled or dark crusted red meat is also a risk factor. The crusting of meat can form heterocyclic aromatic amines (HAAs), which are carcinogenic. You can reduce the ill effects from HAAs and PAHs by cooking red meat at low heat. Additionally, eating meat with cruciferous vegetables. such as broccoli or Brussels sprouts, or marinating [2, 3] the meat in spices, especially Caribbean spices, such as allspice berries, for 20+ minutes before cooking can reduce HCA and PAH formation and prevent much of the heat-chemical induced damage.

The health risks of preparing food over an open flame or charcoaling it are not specific to red meat per se, but these methods are more commonly used to prepare red meat than other types of food.

For optimal health, you should probably avoid processed red meats like these.

Overall, regardless of the precise mechanism, there are many potential reasons to avoid processed red meats for optimal health. Processed red meats offer no unique health benefits yet significantly greater potential for harm compared to unprocessed red meats, or other substitutes, such as fish.

Unprocessed red meat's health effects are more contentious. There are several prominent theories link red meat to cardiovascular disease and (colon) cancer.

First, red meat consumption increases trimethylamine N-oxide (TMAO) levels in the body, because carnitine acts as a precursor for TMAO. High TMAO levels seem to adversely affect our cardiovascular health by i.a. impairing platelet function, promoting atherosclerosis, promoting arterial inflammation and inhibiting reverse cholesterol transport. However, L-carnitine supplementation does not seem to negatively affect cardiovascular health and may even reduce cardiovascular events and mortality, despite increasing TMAO levels. L-carnitine is a direct TMAO precursor. Thus, it's unclear if high TMAO levels resulting from red meat consumption are a health concern.

Second, the heme iron in red meat can be problematic in excess. Heme is a pigment bound to iron in meat that gives it its red color. While iron is a highly beneficial

micronutrient for athletes and women are very unlikely to consume too much of it, excessive heme intake can cause inflammation in our gastrointestinal tract and may contribute to the development of colon and stomach cancer, type II diabetes and cardiovascular disease. Heme is strongly scavenged from plasma, so it's unlikely to have adverse effects outside the gut. Heme denatures above 90°C, so in this specific instance high-heat cooking of red meat may be protective. Dietary fiber and anti-oxidants could also render heme harmless.

Third, red meat is rich in glycans containing N-glycolylneuraminic acid (Neu5Gc). Neu5Gc is a 'xeno-auto-antigen' that causes an inflammatory immune system reaction known as xenosialitis. In mice, this can cause cancer and we can also see Neu5Gc in human colorectal cancer cells, which must come from the diet, as the body does not produce any Neu5Gc. However, there is no direct evidence of Neu5Gc induced harmful effects in humans.

Epidemiological data support the mechanistic evidence that red meat may be inherently unhealthy. Multiple meta-analyses of epidemiological research found red meat consumption is associated with increased cancer risk, cardiovascular disease and all-cause mortality [2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12] although one 2022 meta-analysis of cohort studies did not find the relation was significant for overall cardiovascular disease mortality risk. The relations are generally stronger and more consistent for processed red meat than unprocessed red meat, but unprocessed red meat still presents modest hazard with seemingly linear dose-response effects. The carcinogenic effects of processed red meat consumption are likely the main reason vegetarians have a lower risk of cancer, particularly gastrointestinal cancers. Processed but not unprocessed red meat consumption also strongly correlates with the risk of developing type II diabetes.

However, epidemiological data are limited by their inability to establish more than correlation. People that eat more red meat typically have a substantially worse overall lifestyle than those that consume less meat [2] and they're less wealthy. It's thus plausible that any of these other factors is the true culprit, not red meat. As Alexander et al. (2011) concluded: "Colinearity between red meat intake and other dietary factors (e.g. Western lifestyle, high intake of refined sugars and alcohol, low intake of fruits, vegetables and fibre) and behavioural factors (e.g. low physical activity, high smoking prevalence, high body mass index) limit the ability to analytically isolate the independent effects of red meat consumption. Because of these factors, the currently available epidemiologic evidence is not sufficient to support an independent positive association between red meat consumption and [adverse health outcomes]."

One method to check if a correlation is causative is to use the Bradford Hill criteria. There are 9 aspects of a correlation that make it more likely to be causal in nature, such as consistency in various contexts, a high strength of the correlation and logical temporality: the cause has to precede the outcome, not the other way around. An umbrella systematic review of reviews by Hill et al. (2022) used this method and concluded there is no compelling evidence that red meat consumption *causes* cardiovascular disease. "We infer that a causal relationship is not likely present between red and processed meat intakes and cardiovascular disease risk." Causality was only supported for the correlation between processed red meat intake and type II diabetes. The correlations between unprocessed red meat intake and cardiovascular disease are not strong in most studies (less than 20% risk ratio). Red meat intake's correlations with adverse health outcomes are also not specific to the plausible risk factors. For example, red meat consumption correlates with accidental deaths in multiple studies. Obviously, eating red meat cannot logically make you get into a car crash. Finally, the correlations between red meat consumption and adverse health outcomes do not show up in controlled experiments.

Randomized controlled trials (RCTs) show considerably less harmful effects of red meat than the epidemiological data.

- A 2019 meta-analysis of RCTs concluded that diets higher and lower in red meat overall have similar effects on our cholesterol profile and blood pressure, depending on what red meat is replaced with.
- These findings align with a 2016 meta-analysis finding similar cardiovascular health effects of diets with more than and lower than 0.5 servings of red meat per day.
- In 2020, another meta-analysis of RCTs found no relationship between red meat intake, primarily from lean, unprocessed meats, and markers of diabetes risk or inflammation.
- In 2024, a meta-analysis of 20 RCTs found no effect of beef intake on cardiovascular disease risk markers, including blood pressure and cholesterol levels, including apolipoprotein B, except for a small negative effect on 'bad' LDL-cholesterol levels that became insignificant after removing 1 study (~2.7 mg/dL average difference).

We also have a 2012 meta-analysis finding similar effects of beef, poultry and fish on blood lipids. However, when red meat was specifically compared with high-quality plants foods, notably whole grains, legumes, nuts, fruits and vegetables, the diets with red meat had worse health outcomes, in particular a lesser decrease in LDL-cholesterol. An RCT by Bergeron et al. (2019) confirmed that (red) meat intake increases LDL-cholesterol and apolipoprotein B (apoB) levels compared with plant proteins. However, only large LDL-particles increased in number. Large LDL particles are less likely to get stuck and clog up your arteries and might not be associated with as much cardiovascular risk as smaller LDL particles, although when they do get stuck, they could do more damage. The favorable health effects of plants over red meat are in line with a 2018 meta-analysis of RCTs on a comprehensive panel of disease markers.

Overall, RCT data indicate that unprocessed red meat is much like saturated fat: it can be part of an overall healthy diet without negative health effects and even some positive health effects, but for optimal health it's overshadowed by plants.

In 2019, the Annals of Internal Medicine published what's currently arguably the most comprehensive review on the health effects of red meat. After weighing the evidence of 5 new systematic reviews of the literature, 11 out of 14 authors voted to condone the consumption of red meat. The 3 remaining authors casted a weak vote in favor of restricting red meat consumption. Interestingly, recommendations for processed and unprocessed red meat intake did not differ. Although the vast majority of risk estimates favored lower intakes of red meat and not a single analysis found significant health benefits of higher red meat intakes, the authors deemed the quality of evidence low to very low and the effect sizes too low to be practically meaningful. Most risk estimates suggested that a reduction of 3 weekly servings of red meat per week affected the incidence of cancer, cardiovascular disease and all-cause mortality less than 1%.

Shortly after, another umbrella review of systematic reviews and meta-analyses by Händel et al. (2019), specifically about processed red meats, confirmed that the quality of research is poor. However, they found significantly higher risk estimates for various morbidity and mortality measures up to 91% when comparing the lowest vs. highest processed red meat intakes. Another overview of systematic reviews and meta-analyses by Jakobsen et al. (2021) again concluded the evidence from cohort studies on the relation between meat consumption and adverse health effects is critically low.

The World Cancer Research Fund recommends to largely avoid processed red meats and to limit the consumption of unprocessed red meats to no more than 750 grams of raw meat per week. Somewhat contrastingly, The Dietary Guidelines for Americans

2020-25 actively recommend a total weekly intake of meats and eggs of approximately 750 grams per week to provide nutritious, high-quality protein. The guidelines do not differentiate between lean, unprocessed red meats and poultry. They only recommend avoiding processed red meats. Strength trainees should be able to add at least 20% to these numbers in line with their increased nutritional requirements, so a good guideline for strength trainees is to consume up to 1 kg of unprocessed red meat per week.

Grass-fed meat

As for if you should buy grass-fed meat, grass-fed meat is theoretically better for your health, but the cost-benefit of purchasing grass-fed meat is very poor compared to, say, fish. While generally far more expensive, whether meat is grass-fed makes only a small difference in nutritional value [2] and in RCTs we see no significant effects of grass-fed vs grain-fed meat on people's body composition, insulin sensitivity, cholesterol profile, triglycerides or blood pressure [2].

Conclusion

It's likely best for your health to avoid consuming any processed red meats and to limit the consumption of unprocessed red meats to what you need for its nutrients. A reasonable maximum for strength trainees is 1 kg per week. More than this might have adverse long-term health effects, although the best controlled research does not find adverse acute effects in the context of an overall healthy diet. When you prepare red meat, take care not to expose it to open flames or extremely high heat and not to burn it. The safest red meat preparations are probably rare steaks and boiled meats. Regular pan frying also doesn't seem very risky. To prevent inflammatory or oxidative damage, consume red meat in meals with strongly anti-inflammatory foods like vegetables, fruits and spices.

Poultry

Poultry is basically red meat lite, literally in the sense that it's white meat, and figuratively speaking in the sense that it doesn't have the cardiovascular and carcinogenic health risks. In fact, people that consume more white meat have lower cardiovascular and all-cause mortality or at worst similar cardiovascular mortality rates. While randomized controlled trials find little difference in cardiovascular health biomarker changes between white and red meat, epidemiological research finds people that consume more white meat tend to have a lower risk of cancer [2, 3, 4, 5] and a lower incidence of type II diabetes and cardiovascular disease.

Consuming white meat comes with fewer health risks than red meat, but it also comes with fewer nutrients than red meats or fish. Poultry organ meat is highly nutritious though: chicken kidney and liver are absolute nutrient bombs and everyone should consider eating them occasionally, particularly women when they need extra iron intake. Men may even need to limit their consumption to 2-3x per week to avoid iron toxicity.

Conclusion

Poultry is a safe source of high-quality protein with decent nutritional value.

Fish

Imagine the health benefits of poultry with the nutrient density of red meat and the addition of omega-3s. That's basically fish. The health benefits of fish are well-established, with several analyses of both epidemiological and RCT data concluding high fish consumption is associated with reduced mortality [2, 3, 4, 5, 6]. Fish consumption is not associated with reduced cancer mortality though. Randomized controlled trials find improvements in several health biomarkers which can explain why eating fish could make you live longer and healthier, including lower triglyceride levels (without a notable effect on cholesterol levels), reduced symptoms of rheumatoid arthritis, a lower heart rate, reduced blood pressure and lower risk of coronary heart disease. Fish (oil) consumption has potent anti-inflammatory effects [2, 3, 4] but does not consistently improve insulin sensitivity, in contrast to earlier evidence.

Fish can be prepared in various ways without much effect on its health benefits, but you shouldn't deep-fry fish (nor most other foods). Deep-frying fish can oxidize the PUFAs and form trans fats. The available data suggest deep-fried fish consumption has adverse health effects, in contrast to the well-established health benefits of non-fried fish.

It doesn't matter if you consume farmed or wild fish. Both are great. While wild fish is commonly believed to taste better and be healthier, during blind taste testing most people cannot discern the difference and the difference in nutritional value is small, not enough to have significant health differences [2, 3]. The difference in taste and nutritional value varies more due to feed and season than whether the fish grew up in a farm or in the wild. Farming also has several advantages over catching wild fish.

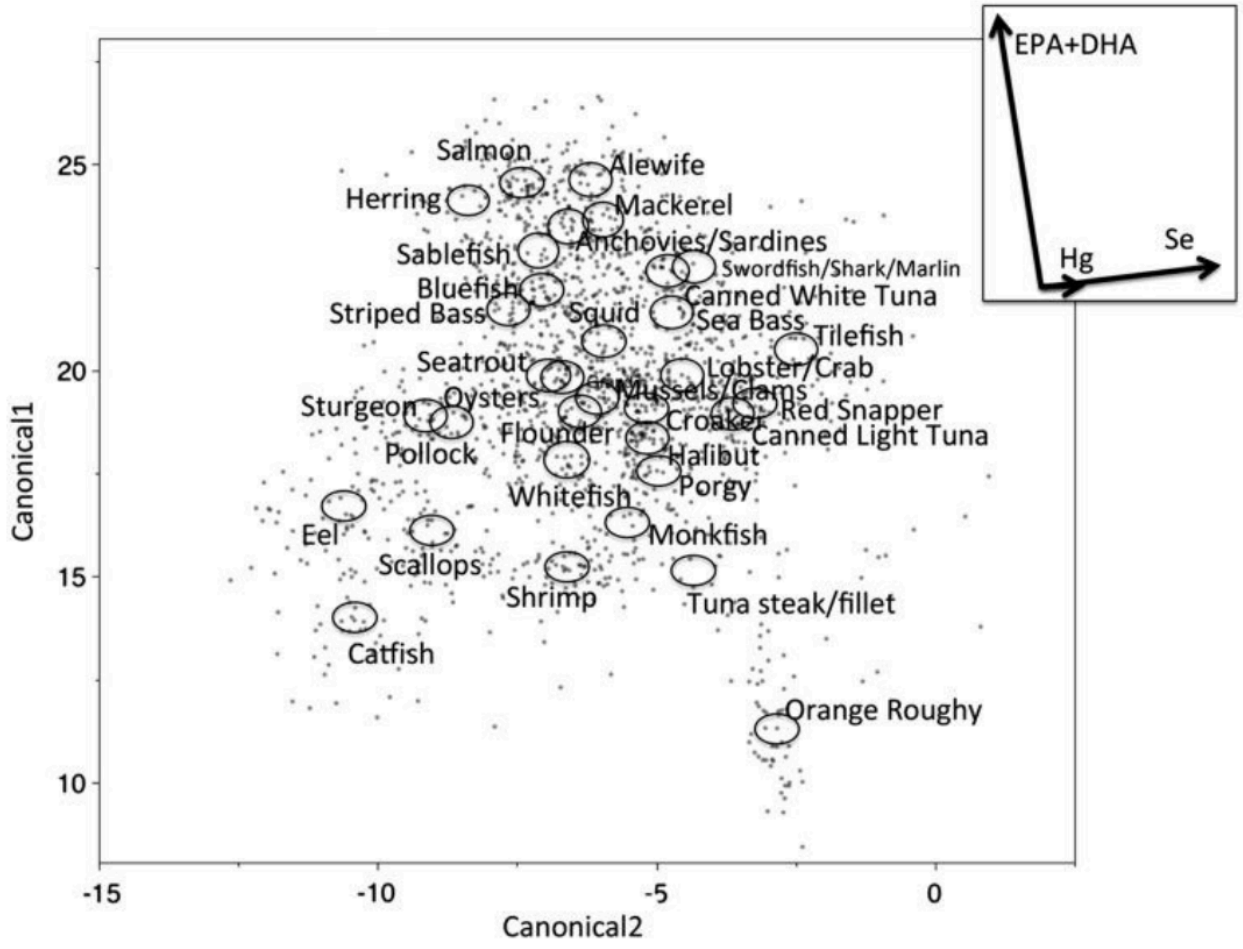
- Farmed salmon is higher in omega-3s than wild salmon because it's fattier (good from a budget point of view, not good from an omega-3-to-calorie point of view though).
- Farming fish allows for better control of toxicity.
- Farmed fish is often fresher, ironically, as it doesn't have to be caught and transported to land.

As Verbeke et al. put it: "consumers' opinions and beliefs about farmed fish are mainly based on emotion and image transfer from intensive terrestrial livestock production rather than on awareness and factual knowledge of aquaculture." In other words, the health benefits of wild vs. farmed fish are massively overblown and for most people it's not worth the added price tag to buy wild fish. You may still prefer to buy wild fish for ethical reasons though of course.

It seems for every healthy food people manage to find a reason not to consume it and, ironically, instead eat their favorite food that we know for sure isn't good for them. Sarcasm aside, what about the concern of toxic mercury in fish? While mercury toxicity is a known risk, there is no direct research showing any adverse health effects of high fish consumption. The health benefits of fish consumption generally outweigh any potential adverse effects of its mercury toxicity [2]. Fish likely has far lower potential for mercury toxicity than isolated mercury because of its bound anti-oxidants, notably selenium [2, 3, 4]. Mercury is toxic in part because it binds to selenium, rendering selenoenzymes unable to perform their vital functions in the body, but that's not much of a problem if you just consume more selenium. Most fish has more selenium than mercury and this significantly reduces the neurotoxic potential of mercury.

Children and pregnant mothers are a notable exception, as children are much more vulnerable to mercury toxicity than fully developed adults.

If you consume very large amounts of fish and you are worried about your mercury intake, you may want to limit the types of fish you eat to the ones in the top left corner of the graph below compared to the bottom right. These kinds of fish, mostly small forage fish instead of larger predatory fish, have relatively high levels of omega-3 fatty acids and low levels of mercury, since mercury accumulates in fish that eat other fish (bioaccumulation). Dolphin and whale have also been reported to contain very high mercury levels.



Conclusion

Fish is a very healthy nutritional powerhouse. Eat it. Frozen and canned fish are good budget options. If you don’t eat fish, you should supplement omega-3s (see supplements module).

Eggs

Eggs are a highly nutritious source of top-quality protein. Eggs are literally the building blocks to form an animal, so they're high in many nutrients, including a complete amino acid profile.

- Eggs are rich in B-vitamins (except niacin) and have a decent amount of all minerals.
- Eggs contain several anti-oxidants with established health benefits, like lutein and zeaxanthin.
- Eggs are a great source of the essential nutrient choline, rivaled only by liver meat. Choline deficiency can cause liver and cognitive problems, as well as muscle damage. However, deficiency is very rare in non-vegetarians and choline supplementation does not seem to offer any health benefits.

The fatty acid profile of Western eggs is quite balanced [2]. While about a third of their fatty acids are saturated, that proportion keeps saturated fat under the commonly recommended but controversial 10% of energy intake when you get 30% of your calories from fat and those calories all come from eggs. Moreover, about half of the fatty acids in eggs are mono-unsaturated (MUFAs), primarily in the form of oleic acid, the same fatty acid that makes up most of the fat in olive oil. The MUFAs should help counteract any negative effects of the saturated fat on blood lipids.

For optimal health, it may be worth getting omega-3 eggs from chickens that were fed flaxseed or fish oil. Omega-3 eggs are often still very affordable due to the low base price of eggs and they have a couple percent less saturated fat and correspondingly 7% instead of 1% omega-3 fat [2]. However, even in omega-3 eggs only 2% of the fat is DHA and EPA is not present in appreciable amounts. Omega-3 eggs also have concentrations of some vitamins, such as vitamin E and D.

Note that ‘organic’ and ‘free-range’ are claims with little concrete legal definition. What primarily matters is what the animal ate. Organic crap is still crap.

Despite their good nutrient profile, eggs they have a reputation for being little cholesterol bombs that clog up your arteries faster than if you’d try to insert them directly in there. It’s true that eggs are high in cholesterol, but as you learned in the course module on dietary fat and cholesterol, for most people, how much cholesterol you consume in your diet does not significantly influence how much cholesterol is in your blood. Cholesterol serum levels are highly regulated. The body changes its synthesis, absorption and excretion based on the dietary cholesterol intake. Moreover, dietary cholesterol intake does not consistently cause or correlate with cardiovascular disease. Similarly, egg consumption does not increase cholesterol levels in 70% of the population and even in the 30% of hyper-responders, LDL and HDL cholesterol both tend to increase similarly [2, 3]. Most lines of research find that eggs do not harm our health.

- Multiple randomized controlled trials up to a year in both healthy and (pre)diabetic individuals have found no significant differences in cardiovascular, glycemic or inflammatory health biomarkers between groups consuming up to 3 eggs a day and groups with lower egg intakes [2, 3, 4, 5, 6]. Some even favored higher egg consumption [1, 2].
- A systematic review of RCTs by Richard et al. (2017) concluded diets with 6-12 eggs per week had no adverse glycemic or cardiovascular health effects in type II diabetics or those at risk for diabetes.
- A systematic review of RCTs by Wang et al. (2019) found no differences in blood pressures or blood lipids between groups consuming fewer than 4 or 4+ eggs per week. However, compared to egg substitutes, eggs increased both HDL- and LDL-cholesterol.

- A 2018 meta-analysis of observational data in China found that people eating 7+ eggs per week had the same all-cause mortality as those that ate almost no eggs and were even at a slightly reduced risk of stroke.
- An independent 2019 review of the health effects of eggs by Godbert et al. concluded eggs are highly nutritious and safe.
- A 2019 systematic review of 7 systematic reviews and 15 meta-analyses by Mah et al. concluded egg consumption has a neutral effect on cardiometabolic health. Other than some inconsistent cross-sectional relations between egg consumption and cardiovascular problems, namely heart failure, more rigorous controlled interventions quite consistently show no adverse health effects, not even in diabetics.
- Dehghan et al. (2020) performed a massive, global, prospective epidemiological analysis with the conclusion: “In 3 large international prospective studies including ~177k individuals, 12k deaths, and 13k cardiovascular disease (CVD) events from 50 countries in 6 continents, we did not find significant associations between egg intake and blood lipids, mortality, or major CVD events.”
- Mousavi et al. (2022) performed a meta-analysis of 32 prospective cohort studies and found no relation between egg intake and all-cause mortality.
- A 2022 meta-analysis of observational studies by Ding & Zhang found that a higher egg consumption was associated with a *lower* rate of metabolic syndrome.

However, it’s worth noting that some observational studies did find evidence for adverse effects. Given that these are minority findings contradicted by other, larger analyses, it’s plausible these effects were confounded by other correlates of egg intake, such as saturated fat intake or low socio-economic status.

- A meta-analysis of prospective cohort studies by Yang et al. (2022) found a significant relationship between egg intake and all-cause mortality, but they rated their certainty of evidence as 'very low'.
- A meta-analysis of prospective cohort studies by Bechthold et al. (2019) found that egg consumption was related to heart failure risk, but there was no relation with coronary heart disease or stroke risk.

Of course, some strength athletes will scoff at 12 eggs per week. How about a carton a *day*? There's no controlled research on these intakes, but a clinic by Hirshowitz et al. (1975) fed their clients with severe burns 30-40 eggs per day and serum cholesterol and lipoprotein levels remained normal throughout the period of study without any reported side-effects. We also have a case study of an 88-year-old man who ate 25 eggs a day for several years. His cholesterol levels were normal.

You can also consume eggs raw. The risk of bacterial or viral infection is minimal in sanitary conditions. However, up to ~50% of raw egg's protein is not digested or absorbed in the small intestine [2], so you need about twice as much protein from raw eggs as from cooked eggs to cover your protein requirements.

Summary

Eggs do not seem to be bad for your health and they're very nutritious. Most of the nutrients are in the yolk, so the only reason to eat pure egg whites is for satiety or for baking purposes. Whole eggs are still quite satiating for a high fat food, so combined with their balanced fatty acid profile, especially in the case of omega-3 eggs, eggs are a good protein source for strength trainees. However, if you consume multiple per day, it's worth doing bloodwork to check that you're not a hyperresponder to cholesterol consumption.

Dairy

Dairy is a top-quality protein and calcium source with an excellent satiety profile relative to its fat content. Dairy's bioavailability of calcium is significantly higher than that of supplements and dairy intake is consistently associated with better bone density, reduced fracture risk and lower rates of osteoporosis. Unpasteurized dairy, especially fermented dairy, is also rich in probiotics that can significantly improve our digestive health. Pasteurization kills most beneficial bacteria, but some dairy products these days have probiotics reinserted into them.

Despite its beneficial nutrients, dairy is often demonized, mostly because of its saturated fat content. A 2016 review paper sought to end the question of whether dairy is healthy once and for all with the appropriate title: "Milk and dairy products: good or bad for human health? An assessment of the totality of scientific evidence." The review concluded that dairy intake is associated with a low body fat percentage, increased muscle mass, improved bone density, reduced risk of various cancers, a trend towards reduced risk of type II diabetes and a reduced risk of cardiovascular disease, particularly stroke. There was no relation between dairy intake and all-cause mortality, which is further supported by a 2019 meta-analysis of meta-analyses of prospective cohort studies.

The form of dairy matters considerably for at least 2 reasons. First, the dairy fat matrix seems to influence how detrimental the saturated fat in dairy is. Dairy fat has more adverse effects on blood lipids when it's not contained within the dairy food matrix [2]. For example, butter has more adverse effects on our blood lipids than cheese [2] or cream. Thus, the general trend for more processed food to become unhealthier seems to apply to dairy. As a result, full-fat dairy, such as whole milk, and low-fat dairy, such as skimmed milk, tend to have similar health effects [2, 3]. There's even a weak trend

for full-fat dairy to exert slightly more positive than neutral health effects, but unsaturated fat sources tend to be healthier, as usual. Cheese also has a surprisingly good track record considering it's very high in saturated fat and calories. People that eat more cheese are generally not at greater risk of developing cardiovascular (heart) problems [2]. A 2023 large-scale meta-analysis even found that higher cheese consumption was associated with lower all-cause mortality, cardiovascular disease and type II diabetes with neutral effects on most other health markers. Cheese is rich in several nutrients, including the uncommonly found vitamin K2. All dairy fat sources still tend to be worse than unsaturated fat sources though.

The second significant determinant of a dairy's food's health effects is whether it's fermented. Fermented, unpasteurized dairy is rich in live probiotics and tends to result in better health outcomes than milk, cream and butter according to a 2021 systematic review: "health-promoting properties of fermented milk products may be due, in part, to the biosynthesis or release of bioactive compounds resulting from the fermentation process, including bioactive peptides with antihypertensive, antimicrobial, antioxidative, and immune-modulatory activities. Lactic acid bacteria may also produce bacteriocins, biogenic amines, and exopolysaccharides." Examples of very healthy fermented dairy products include unpasteurized kefir and yogurt.

A third potential factor related to saturated dairy fat's better than expected health effects is its relatively high concentration of the rare odd-chain saturated fatty acids (OC-SFAs), in particular pentadecanoic acid (C15:0) and heptadecanoic acid (C17:0). While dairy fat still only consists of 1.5-2.5% OC-SFAs, dairy fat is the most common source of odd-chain saturated fatty acids in humans and the plasma levels of these fatty acids in the body has been correlated with good health. There is therefore speculation that OC-SFAs may be beneficial for our health, but most of this speculation comes from industry sponsored research, tracing back to Epitracker, who sell OC-SFA

supplements. There's currently no causal evidence that the consumption of OC-SFAs even alters its levels in the body, let alone that they improve our health. In fact, it seems that human plasma maintains a ratio of C15:0 to C17:0 of approximately 1:2, in contrast to the expected 2:1 ratio in dairy fat, suggesting that the body can produce its own OC-SFAs and regulate its levels, rendering supplementation pointless.

What about the risk of cancer? The relationship between dairy intake and cancer is complex. Most research finds no relation between dairy intake and the risk of cancer [2, 3]. There is even a significant inverse relation between dairy intake and the risk of some types of cancer, such as bladder and colon cancer, probably because of dairy's beneficial probiotics that improve digestive health. The one type of cancer that does appear to be weakly promoted in some of the research is prostate cancer. This was originally thought to result from the increase in IGF-1 concentrations from dairy consumption. However, other research suggests it's calcium overconsumption and not dairy per se that is harmful. A 2015 meta-analysis found that dairy but not low-calcium dairy intake is associated with higher prostate cancer risk. The relation was strongest above 1.5 g of calcium a day, which is ~50% higher than the recommended daily intake. This may cause vitamin D depletion or inherently contribute to the development of cancer. Given the weak and inconsistent relation, however, it's doubtful if men consuming enough vitamin D and not massively overconsuming calcium need to worry about their dairy intake, unless they have a predisposition for prostate cancer. It's also worth noting that higher intakes of whole milk were associated with reduced cancer risk.

Hormones in milk

The wonders of modern technology have given us cows that lactate throughout almost their entire pregnancy, allowing us to milk them the vast majority of the year. A

side-effect from that is that the cows also produce high estrogen and progesterone levels and these could partly end up in the milk. However, most research has found that the amount of biologically active estrogen in Western commercial cow's milk is too low to have estrogenic activity in humans [2].

This may not apply to non-Western countries, as Mongolian cow milk does seem to have significant estrogen and progesterone levels. A 2010 study in Japan found that men drinking 600 ml of full-fat milk from pregnant cows experienced a significant acute increase in estrogen and progesterone levels and a decrease in testosterone levels for 2 hours. However, this small Japanese study did not have a control group. Meals with saturated fat, regardless of whether it comes from dairy, can transiently decrease testosterone levels, yet they increase them over the long term, so this study result may not say anything about long-term hormone levels. The researchers also studied women drinking 500 ml of full-fat milk for 21 days to see if the milk affected their menstrual cycle. It did not.

Other than this uncontrolled study, we have scant RCT data in humans on the effect of dairy intake on hormonal and reproductive health. In mice, experimental data show no effect of cow's milk on plasma sex hormone levels or sex organ weights until the milk's hormone concentrations are artificially increased over 1000-fold. In other words, it took way more estrogen exposure than you could possibly get from drinking commercial milk to suffer health effects. In humans, we are left mostly with epidemiological data and all its limitations. These data find no consistent relation between dairy intake and reproductive health [2, 3]. Some studies find no relation, others negative relations and others positive relations between dairy intake on reproductive health [2, 3, 4], suggesting the relations are spurious or driven by other covariates. Similarly, long-term research finds no consistent pattern of dairy intake increasing estrogen and progesterone levels or decreasing testosterone levels. In men, even very high dairy

intakes are not consistently associated with altered sex hormone levels. In women, if anything there is a trend for high dairy intakes to reduce estrogen levels without affecting other hormone levels, but dairy intake isn't associated with menstrual cycle functioning.

Any hormonal effects of dairy would also have to be too low to significantly affect our body composition, at least over the course of months. Regular dairy consumption is not associated with body composition changes under calorie-controlled conditions. If anything, there's a trend in some studies of increased fat-free mass and decreased body fat levels. These effects are likely purely mediated by the relatively high protein content and satiety index of dairy products.

In sum, if there are significant amounts of estrogen or progesterone in cow's milk in the first place, the concentrations seem to be too low to have consistent, long-term health effects.

Lactose intolerance

Given all the positive research and the nutritional value of dairy, how come dairy has such a bad stigma attached to it? The reason is likely lactose intolerance. In evolutionary terms, humans have only recently been introduced to cow's milk and up until that time most people did not produce lact**a**se, the enzyme used to digest lact**o**se, the sugar found in milk. The lactase enzyme breaks down lactose into glucose (and galactose, which is then also converted to glucose).

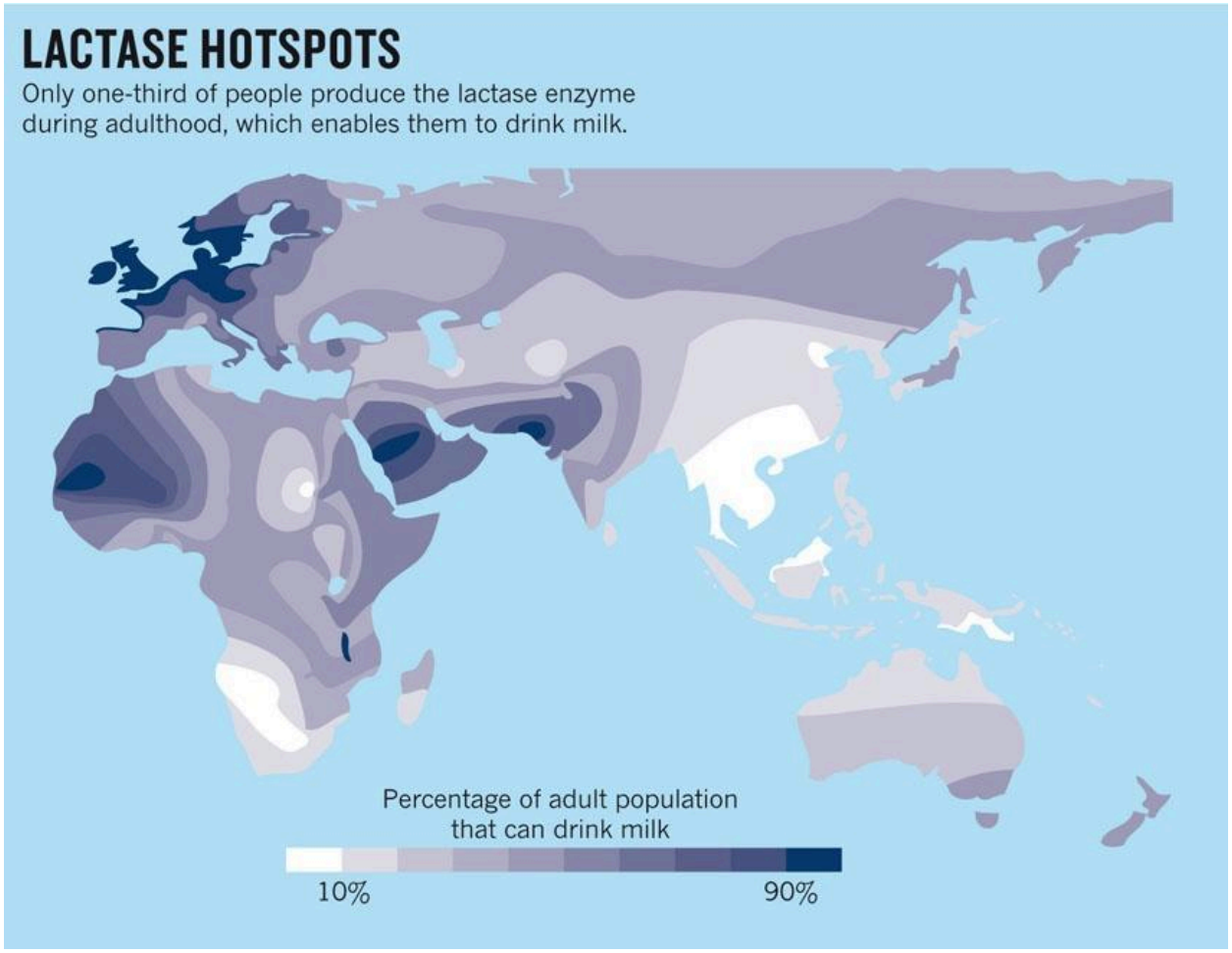
Individuals that do not produce enough lactase generally suffer from diarrhea and other digestive problems when they consume lactose containing dairy. Bodybuilders often

mistake bloating for fat gain (the same reason they think estrogen makes you fat). So bodybuilders scraped dairy off the ‘clean foods’ list.

The lactose intolerance problem was solved in the Middle East around 11.000 years ago during the agricultural revolution. The answer was fermenting the dairy, which breaks a part of the lactose in dairy down so that your body doesn’t have to. This led to the invention of yogurts and cheeses.

Fortunately, evolution had an even better solution. In contrast to most digestive changes required to tolerate new foods, it turns out the genetic mutation required to produce the lactase enzyme in humans was very minor, because infants can already produce lactase to digest the lactose in mother’s milk. Specifically, lactose tolerance seems to be linked to a single nucleotide in which the DNA base cytosine changed to thymine in a genomic region not far from the lactase gene.

Since dairy tolerance provided a huge evolutionary advantage, among the strongest yet seen for any gene in the genome, by providing a readily available source of all 3 macronutrients and many micronutrients, this genetic mutation spread quickly throughout Northern Europe. Unfortunately for the rest of the world, oceans have to date functioned as a strong barrier against further spread of dairy tolerance. Just over 1 in 3 individuals worldwide have perfect lactose tolerance and these individuals are almost all of European descent with a few ‘lactase hotspots’ in West Africa, South Asia and the Middle East (see maps below).


LACTASE HOTSPOTS
Only one-third of people produce the lactase enzyme during adulthood, which enables them to drink milk.
Percentage of adult population that can drink milk
10%
90%

Source

If you are one of the lucky ones that has no digestive issues with dairy, by all means make dairy a regular part of your diet. If you're lactose intolerant, you can still reap the benefits of dairy by consuming fermented dairy foods, lactose-free dairy or dairy with added lactase enzyme to digest the lactose. A good rule of thumb is to supplement 9000 international units (IU) lactase for every 12 grams of lactose in the meal. Alternatively, consume the probiotics Lactobacillus spp. and Bifidobacterium longum or Bifidobacterium animalis. These help your gut produce lactase. You get them from dairy or supplements. This explains why some people can become tolerant to regular

dairy by consuming fermented dairy or lacto-free dairy. Some people are so intolerant they still experience symptoms even with lactase or probiotic supplementation though.

Fermented dairy is likely better than regular dairy anyway due to its added probiotic benefits for gut health (discussed further in the course topic on supplementation). You may also tolerate raw (unpasteurized) dairy better.

➢ Recommended reading

The raw milk reality [series]

Summary

Dairy is a decently nutritious food category that's particularly rich in calcium and high-quality protein. Dairy as a category tends to have neutral effects on health biomarkers. Fermented and relatively unprocessed dairy, such as yogurt or kefir, tends to have positive effects, even if it's full-fat, whereas more processed dairy rich in saturated fats, such as butter, tends to have adverse effects on cardiovascular health. Overall, if you're not intolerant to lactose or one of the proteins in dairy, dairy can be a great component of a healthy diet. If you are intolerant, you may still tolerate dairy with added lactase. If you can buy raw dairy and have a good immune system, that's probably the healthiest option.

Vegetarian diets

Vegetarian diets have an excellent health record in the literature, particularly the epidemiological literature. However, vegetarians almost by definition tend to more health conscious than the average meat eater. Someone on a vegetarian diet is on a diet and a very restrictive one at that, so they're evidently more health conscious and invested in their diet than the average person. In many studies the vegetarian group has a lower body fat percentage, a higher fiber intake, a higher vitamin intake and a higher intake of anti-oxidants than the meat-eating group.

Despite these advantages, vegetarians and vegans don't consistently have better overall health than omnivores. On average, vegetarians seem healthier than meat eaters [2, 3], but when we specifically compare vegetarians with *comparable* meat eaters in terms of bodyweight and lifestyle, all-cause mortality rates appear to be the same in both groups. Moreover, studies comparing all-cause mortality rates between vegetarians and omnivores have produced mixed results with many null findings and even some negative findings, e.g.

- In one prospective cohort study, vegetarians in the UK had similar all-cause mortality as comparable meat-eaters.
- In another pooled analysis of 2 large prospective studies in the UK, vegetarians had a lower risk of cancer than meat eaters, but fish eaters had just as little risk of developing cancer as vegetarians.
- One author's mini-review found lower all-cause mortality in vegetarians than omnivores, mostly due to improved cardiovascular health, but this came with increased risk of non-communicable disease, particularly blood disorders.
- An older review of prospective studies found similar all-cause mortality rates in vegetarians and meat eaters.

- A review of vegetarianism in Austria found that "a vegetarian diet is associated with poorer health (higher incidences of cancer, allergies, and mental health disorders), a higher need for health care, and poorer quality of life" in spite of vegetarians overall being leaner and consuming less alcohol than meat eaters.
- A subsequent cohort analysis of the elderly found similar all-cause mortality rates in vegetarians and non-vegetarians despite the vegetarians living an overall significantly healthier lifestyle.

The mixed results make perfect sense if we evaluate the health effects of each food group individually. While plants offer certain health benefits and nutrients, animal foods do too. While plants shine in terms of vitamins, anti-oxidants and phytochemicals, animal foods have a higher protein quality and are typically richer in bioavailable minerals, especially iron, beneficial fatty acids like omega-3s (EPA and DHA specifically) and B-vitamins. It makes sense then that multiple studies have found health benefits from adding animal foods to a vegan diet and vegetarian diets increase the risk of nutrient deficiencies. For example, a 2022 meta-analysis found that Mediterranean diets are more effective to reduce systemic inflammation than vegetarian or vegan diets. Overall, 'flexitarian diets' tend to be healthier than vegan diets.

There is also considerable evidence that vegetarian diets are associated with mental health problems. Based on a 2020 systematic review "comprising 160,257 participants from varied geographic regions, including Europe, Asia, North America, and Oceania, aged 11 to 96 years, there is clear evidence that meat-abstention is associated with higher rates or risk of depression, anxiety, and self-harm." However, longitudinal data suggest the onset of mental health problems precedes that of adopting a meat-free diet. Thus, it seems more likely that people with mental health problems are drawn to vegetarian diets rather than that vegetarian diets necessarily cause mental health

problems. That said, certain deficiencies that are common in vegetarian diets have been linked to mental health problems, notably those of B-vitamins and omega-3s.

Conclusion

Vegetarians and even vegans are typically healthier than the average person, but they majorly increase the risk of multiple nutrient deficiencies. While a case can be made to exclude all (processed) red meat, it's very difficult to argue for the abstinence of poultry, dairy or eggs. Avoiding fish in particular is mostly likely detrimental for your health.

This is not to say you can't be a vegetarian for ethical reasons. This module only discusses health.

Olives

No controversy here. Olives are among the healthiest foods on the planet and a paragon of the Mediterranean diet, one of the healthiest diets on the planet [2, 3, 4]. They're rich in fiber, mono-unsaturated fatty acids and phytochemicals, in particular anti-oxidant polyphenols. They're also a decent source of multiple micronutrients. The fats in olives are so healthy even their oil – olive oil – is famously healthy [2, 3]. A 2022 analysis reported major health benefits of virgin olive oil consumption: "Olive oil has significant anti-inflammatory, antioxidant and anti-atherosclerotic properties as well as beneficial effects on endothelial function and blood pressure control. […] Daily moderate consumption of virgin olive oil (1 and 1/2 tablespoons) was associated with a one-third lower risk of all-cause as well as half the risk of cardiovascular mortality. These effects were not seen for common olive oil."

A 2019 meta-analysis of RCTs confirmed that high-phenolic extra virgin olive oil has the most positive effects on health biomarkers, although all types of olive oil are generally healthy. For optimal health, get extra virgin olive oil to keep the oil as unprocessed as possible. Virgin olive oil is made purely mechanically by crushing and pressing the oil out of the olives without high heat. Heat-processing or refining the oil can reduce its polyphenol and other phytochemical content and oxidize some of the fatty acids. The polyphenols in olive oil are responsible for many of its health benefits, so you want to preserve them as well as possible. The polyphenol content of olive oil is generally highest directly after harvesting the oil and decreases thereafter. Thus, the fresher the oil, the healthier it should be.

Coconut

One of the few well-known fatty fruits, coconut oil's fatty acids are almost all saturated (90%), yet coconut oil has become known as a healthy fat in the eye of the public. It's a good source of the rare medium-chain triglycerides (MCTs), as you learned in the topic on ketogenic dieting, which have different metabolic effects than other longer-chain triglycerides. Despite coconut oil's current popularity, most health authorities do not recommend consuming coconut oil because of its saturated fats. Of course, health authorities have been overly fearful of saturated fat for decades, so let's look at what scientific research says about coconut oil's health effects [2, 3].

Most research finds refined coconut oil consumption increases cholesterol levels [2]. Coconut oil is rich in the MCT lauric acid, which is a substrate for apolipoprotein synthesis, including ApoB, the primary marker of predictive of atherosclerosis by cholesterol. Part of the increased cholesterol is HDL-cholesterol, but LDL-cholesterol increases alongside HDL-cholesterol in many studies. The ratio generally changes favorably compared to butter and other saturated fats but not compared to olive oil, vegetable oils or other unsaturated fats, except peanut oil in one study. Unfortunately, there's scant research looking at the effect of coconut consumption on ApoB particle number directly, which would help clarify if the change in cholesterol levels is indeed detrimental. In Menno's experience, there are hyper-responders to coconut oil that suffer a major increase in LDL-cholesterol when they consume a lot of coconut oil even in an otherwise very healthy diet with a reasonably balanced fatty acid profile.

Extra virgin coconut oil and coconut milk seem to have more favorable health effects than refined coconut oil. In contrast to refined coconut oil, extra virgin coconut oil does not raise LDL cholesterol levels according to a 2019 meta-analysis including multiple studies on virgin and extra virgin coconut oil. Virgin coconut oils still increased HDL

cholesterol levels, resulting in an improvement in the overall lipid profile. However, one study, Harris et al. (2017), found virgin coconut oil did increase both types of cholesterol, albeit without unfavorably affecting the ratio, and it increased inflammation in at least one subject. Safflower oil did not affect blood lipids in this study. It's also unclear why virgin coconut oil and coconut milk would affect our cholesterol levels more favorably than non-virgin coconut oil. It may be that non-virgin coconut oils are often hydrogenated during their extra processing and therefore contain trans-fatty acids and it's these trans-fats that are responsible for the rise in cholesterol, not coconut oil's natural fatty acids.

Compared to vegetable oils, coconut oil generally doesn't affect any other health biomarker. Case-control studies find that coconut oil consumption in southeast Asian and Pacific countries is not related to cardiovascular health status. However, coconut flesh rather than oil is often consumed in these countries, which is arguably healthier due to its high fiber, anti-oxidant and micronutritional content. These cultures also typically eat diets rich in fish and plants, which may offset any negative effects of saturated fat.

Despite being a saturated fat, coconut oil is no better for cooking than olive oil. Extra-virgin olive oil has a smoke point of 191° C compared to 177° C for unrefined coconut oil, which puts coconut oil just under the ~180°C temperature of pan frying. Both coconut oil and olive oil, especially extra virgin olive oil, have excellent oxidative stability. Extra virgin olive oil is highly resistant to oxidation because of its high anti-oxidant content. Like most oils, coconut oil doesn't lend itself well to being reheated. Reheated coconut oil has inflammatory and carcinogenic effects in rats.

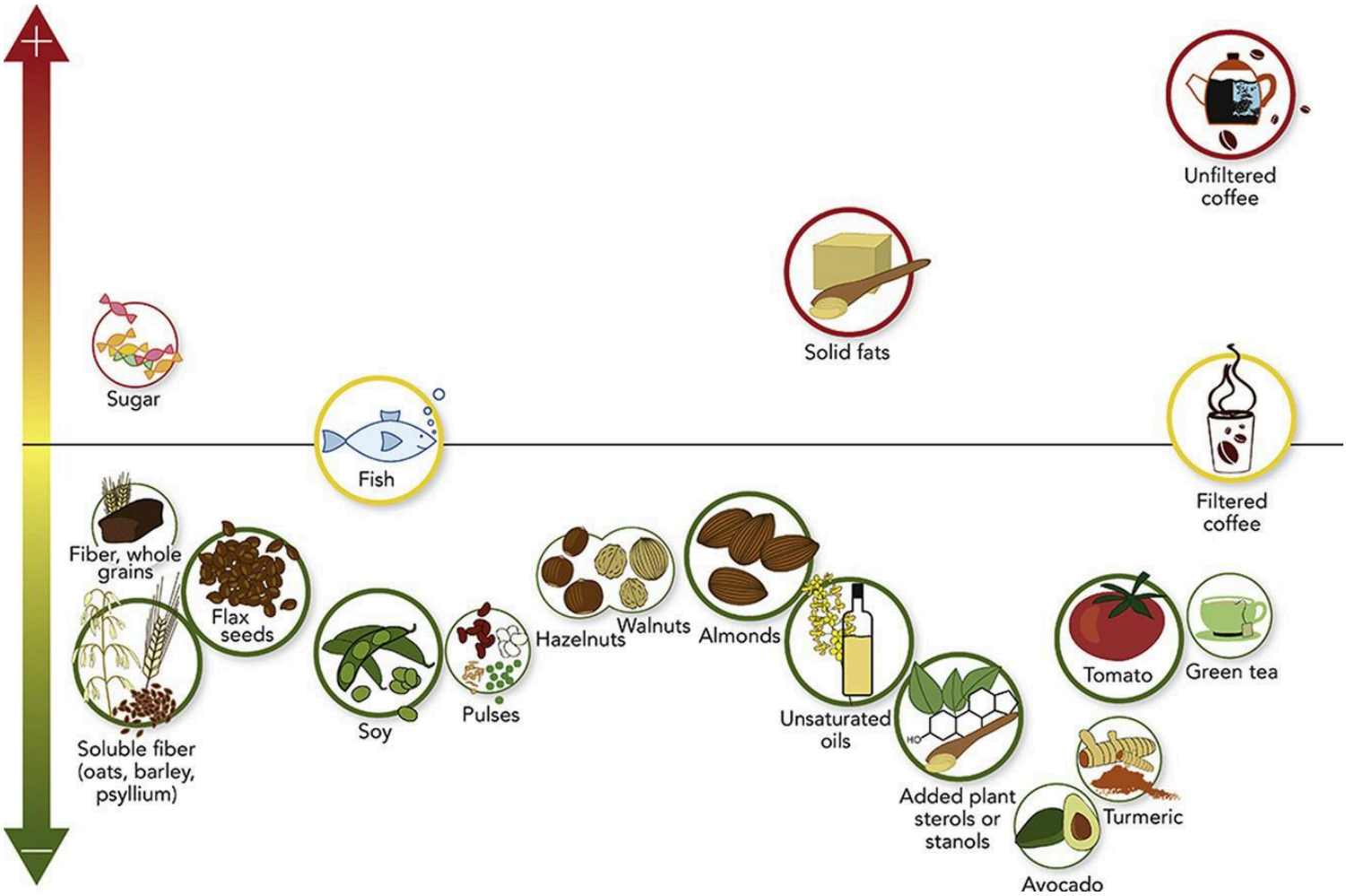
Summary

Refined coconut oil is likely better for your health than most saturated fat sources but worse for your health than many non-saturated fats. Extra virgin coconut oil may be net positive, but it does not yet have the same research support as oils like olive oil. As such, choosing extra virgin is a must when you want to include coconut oil in your diet. Even better, coconut flesh is most likely more health promoting than the oil because of its fiber and micronutritional content. If you consume coconut oil regular, it's advisable to keep an eye on your LDL-cholesterol and ApoB particle number with bloodwork, as some individuals experience major spikes that are not offset by higher HDL-cholesterol levels.

Avocado

Avocado has a nutritional composition one may consider closer to a nut than a fruit, but botanically speaking, avocados are berries. And like most fruits and nuts, avocados are very healthy. They are rich in anti-oxidants, fiber, mono-unsaturated fat and micronutrients. Their highly nutritious yet low carb nutrient profile arguably makes avocados the #1 ketogenic diet fruit. While there may be some sponsorship bias from the Hass Avocado Board in the literature, consuming even a single avocado per day has been found in multiple studies to significantly improve our cholesterol profile and reduce systemic inflammation levels. The combination of anti-oxidations, soluble fiber and primarily mono-unsaturated fat makes avocados a perfect LDL-cholesterol lowering food [2]. There's limited data on long-term health outcomes, but based on the RCT data, health outcomes should be very positive.

Avocado oil theoretically has the same good fatty acid profile, but in practice, most avocado oils are oxidized or adulterated. If you want to use avocado oil for anything, make sure it's virgin avocado oil and it's green.



A 2021 meta-analysis on the best LDL-lowering foods found avocadoes scored best.

[Source]

Grains

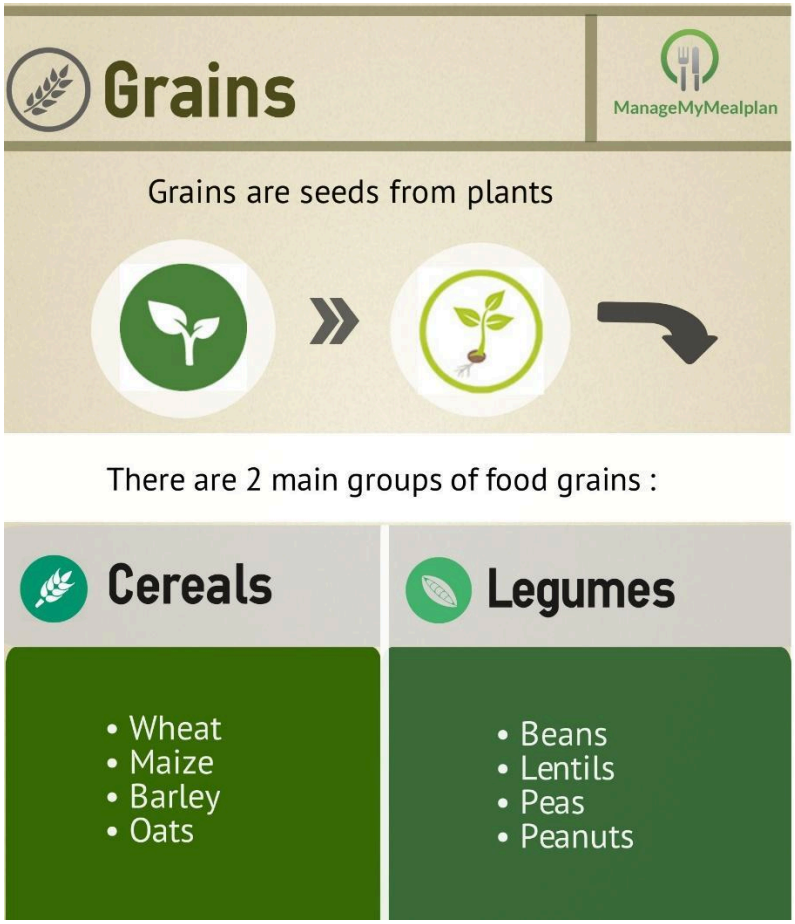
Why don't many bodybuilders eat bread? Is wheat belly a serious phenomenon? Should you avoid gluten? Why do beans give you gas? Is bread healthy? It's time to separate the fear mongering from the science.

Before reviewing the effects of grains for your gains, let's first discuss terminology so that we're talking about the same things here.

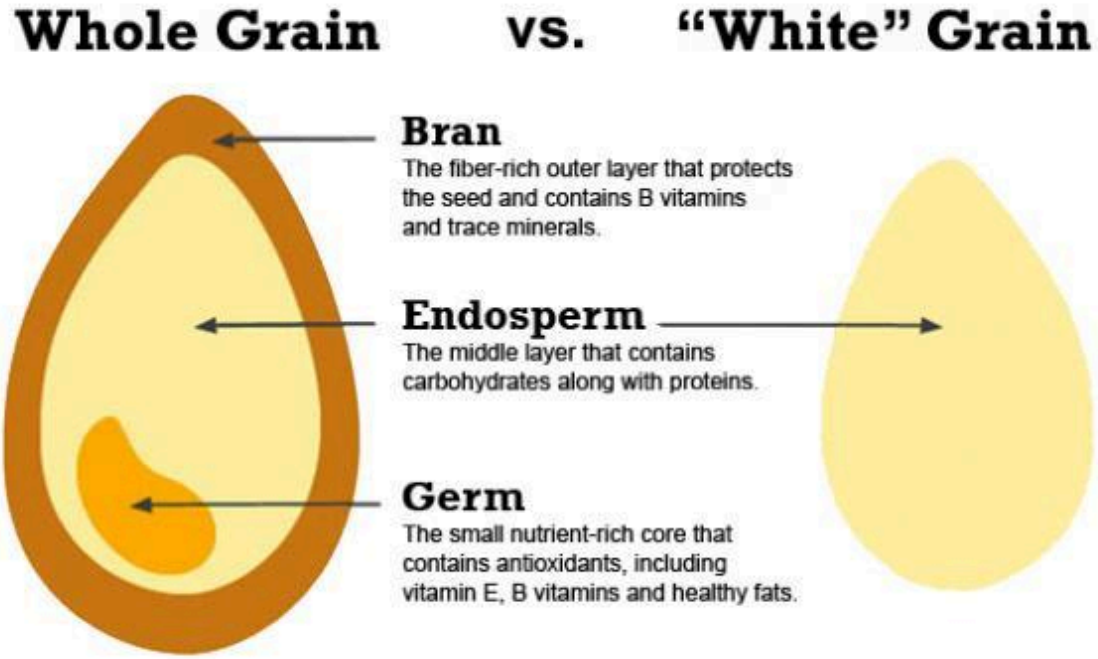
Terminology

Grains are seeds from plants. A lot of those plants together form crops. There are 2 main groups of food grains: cereals and legumes.

1. Cereals are a form of grass. They include wheat, rice, maize (= corn), barley and oats.
2. Legumes include beans, lentils, peas and peanuts. Despite their name, peanuts are technically not a type of nut, though nutritionally they are closer to nuts than legumes.



Cereals can be consumed as whole grains with their bran and germ intact or these can be removed to form refined grains. Whole cereal grains are typically brown and refined grains are typically white, but bleaching and color additives can interchange these colors. Whole cereal grains are far richer in nutrients, because the bran and germ contain most of the micronutrients of whole grains.



The anatomy of cereal grains.

Let's start by looking at legumes.

Are legumes healthy?

There's little controversy here. The answer is yes with strong support in both epidemiological studies as well as RCTs: legume consumption improves many health biomarkers [2, 3, 4]. They are rich in nutrients and beneficial phytochemicals on top of a good amount of dietary fiber and some protein.

Are cereal grains healthy?

This one's trickier. There are a lot of epidemiological studies showing that people that eat more whole grains are healthier and leaner. The problem in concluding anything from this is that whole grain foods are traditionally regarded as a health food, so whole

grain eaters are generally very health conscious. Whether someone chooses to eat 'perhaps not as tasty but healthier' whole grains instead of the 'perhaps not as healthy but tastier' refined grains says a lot about their lifestyle preferences: it's associated with how educated someone is and the consumption of other health foods such as vegetables, fruits and seafood and it's inversely associated with smoking, BMI and consumption of red meat, alcohol, cakes and biscuits [1, 2]. In theory, you can statistically control for these factors, but it's not very reliable due to the large number of confounders and because you can only control for what you know and measure in your dataset ('residual confounding').

The average person's primary sources of energy are processed grain products and soda. It's not surprising then that eating less of those and more whole grains improves someone's health. In other words, the average person's diet is simply so unhealthy that whole grains jump out as a major health food compared to all the processed crap they otherwise eat. Thus, epidemiological evidence can't tell us much about the health effects of cereal grains other than that it's probably healthier to eat whole grains than processed grains. Fortunately, we also have many randomized controlled trials on the health effects of whole grains.

A 2017 systematic review of RCTs on whole grain consumption found no positive effects of whole grain intake on any marker of cardiovascular health, not even compared to refined grains. However, certain whole grains may be healthier than others. At least compared to their refined counterparts, some studies have found that brown rice, compared to an isocaloric diet with white rice, can improve insulin sensitivity, blood pressure, blood flow and inflammation levels [1, 2]. The latter study also found greater fat loss, presumably due to a lower energy intake resulting from the higher fiber intake and lower palatability; however, given that self-reported or planned energy intake were not significantly different between groups, a small effect of lower

energy digestibility or improved gut microbiome health is possible. Moreover, a study by Davy et al. (2002) found that a given fiber intake from oats resulted in greater reduction in LDL-cholesterol than that fiber intake from wheat. HDL-cholesterol or insulin sensitivity were not differently affected though.

The second alleged major health benefit of whole grains is glycemic control. Indeed, whole grains result in a lower glucose and insulin response than refined grains. However, a 2017 meta-analysis of RCTs found no significant chronic effect of whole grain consumption on fasting insulin or glucose levels or insulin resistance. This suggests the benefits of whole grains for diabetes are mediated primarily by body fat percentage and not by inherent protective effects of the whole grains. So people that consume more whole grains are probably at a reduced risk of diabetes because they are leaner than people who consume more refined grains, not because whole grains inherently protect them against diabetes. In fact, grains of any kind are a relatively high-risk food group to consume for type II diabetics compared to fruit, vegetables and other low-carb foods, due to their high glycemic index.

Of the big 3 causes of death, that leaves cancer. A 2016 meta-analysis concluded that the weight of the evidence does not support any relation between the risk of getting cancer and the consumption of whole grains. There was somewhat of a trend for a reduced risk of colorectal cancer specifically, but this is probably entirely due to the fiber intake and cereal fibers appear no more preventive of colorectal cancer than other dietary fibers. While whole grains are often called high-fiber foods, this is only true when expressed as density per 100 grams or in comparison to processed junk foods. On a calorie-equated basis, whole grains are a poor source of fiber compared to many fruits and vegetables: see the fiber charts in the course module on carbohydrates.

A final major health consideration is chronic inflammation. A comprehensive 2019 meta-analysis found no overall effect on inflammation markers of whole grain intake in healthy individuals, compared to a lower intake of whole grains or compared to other grains, most often even refined grains. The researchers corrected prior analyses with methodological problems. A 2014 systematic review of both intervention and associative studies found that whole-grain based diets are generally less effective at reducing inflammation than other diets with a similar glycemic load, indicating grains are generally inferior to other plants like fruits and vegetables. Some data suggest whole grains may reduce inflammation via different mechanisms than fruits and vegetables though, so they may have additive health benefits.

In conclusion, whole grains are probably better than refined grains and certainly better than most of the crap the general population eats, but they're not as beneficial for your health as many fruits, nuts, legumes, vegetables or fish. You can easily thrive without any whole grains in your diet.

Grains for your gains?

For strength trainees, there is a particular concern with basing your diet around grains. Many plants have evolved defense mechanisms to protect their seeds from being eaten by animals. One of these mechanisms is the production of anti-nutrients that make the seed's nutrients impossible or uncomfortable to digest by animals. Anti-nutrients occur in many foods, but grains have a particularly high concentration. Some of these anti-nutrients have positive health effects in humans, like preventing inflammation from high iron intakes. Altogether though, it's safe to say they're undesirable for muscle growth.

For one, anti-nutrients greatly reduce the digestibility of minerals like magnesium and iron. Ironically, grains are often advertised for their high mineral contents, but mineral absorption is exceedingly poor compared to animal foods. On a calorie-equated basis, grains aren't very nutritious in comparison to most vegetables or organ meat to begin with. For example, only 13% of the magnesium in bread containing the anti-nutrient phytic acid is absorbed by the body, compared to 20-40% for most foods [2]. Iron uptake from bread can be as low as 3.8%.

Phytic acid also binds to protein, the crucial building block of your muscles. Several anti-nutrients inhibit trypsin and pepsin, enzymes that your body needs to digest protein. When your body can't absorb the protein from your food, it cannot use it to build muscle tissue. Muscle growth is the result of positive protein balance: greater levels of muscle protein synthesis than protein breakdown. In animals, the effects of anti-nutrients are severe: anti-nutrients can reduce protein digestibility to less than half. In humans, we don't have many data, but Mexican diets with relatively high amounts of anti-nutrients reduced protein digestibility by 23%. Nitrogen balance, a measure of protein balance, decreased by several-fold, as did the digestibility of minerals. Soy's notoriously poor ability to stimulate protein synthesis or inhibit protein breakdown is likely in part because soybeans are loaded with anti-nutrients. A high anti-nutrient content may be another reason why vegetarian diets are associated with lower muscle mass than omnivorous diets even with the same protein intake. (Other reasons include low protein quality and low cholesterol intake.) Similarly, whole, brown rice consumption results in significantly lower nitrogen balance than refined, white rice [2], likely due to the anti-nutrients in whole rice. These anti-nutrients mostly reside in the bran, so white rice does not have many anti-nutrients left: they are removed along with most of the nutrients. The limited research we have on whole bread finds no adverse effects on protein balance, but both studies were sponsored by Nestlé. Ross et al. (2013) found no sustained difference between whole vs. refined grain rich diets on

urinary protein catabolite markers (though they tried to make it sound like there was an effect in their title based on the short-term data). Mey et al. (2021) surprisingly found a whole-grain rich diet *increased* whole-body protein balance compared to a similar refined-grain rich diet with equal macronutrient intakes. They also reported that whole wheat extract stimulated in vitro muscle cells to produce more muscle protein. However, 8 weeks on the different diets did not differentially affect body composition measurements. The contrasting findings of rice and bread are the opposite of what you'd theoretically expect, because rice contains far fewer anti-nutrients than most other grains. Rice typically contains less than a third of the phytic acid that wheat does: see the chart below for an overview of phytic acid concentrations in cereals and legumes. Bodybuilders also traditionally shun wheat in all forms but love white rice, although this may be primarily related to easier digestion.

Table 2. Content of phytic acid/phytate in cereals

Cereals Common names	Taxonomic names	Phytic acid/phytate[a] g/100 g (dw)	References
Maize	*Zea mays*	0.72–2.22	[47–57]
Maize germ		6.39	[20]
Wheat	*Triticum* spp. (~25 species)	0.39–1.35	[48, 49, 51, 57–60]
Wheat bran		2.1–7.3	[20, 46, 51, 53, 59, 60, 61, 72]
Wheat germ		1.14–3.91	[20, 46, 74]
Rice	*Oryza glaberrima/sativa*	0.06–1.08	[47–50, 52, 55, 62, 63, 114]
Rice bran		2.56–8.7	[46, 51, 59, 60, 75]
Barley	*Hordeum vulgare*	0.38–1.16	[51, 53, 57, 58, 60, 64-66, 99]
Sorghum	*Sorghum* spp. *(~30 species)*	0.57–3.35	[50, 51, 55, 67, 73]
Oat	*Avena sativa*	0.42–1.16	[51, 54, 56–58, 60, 61, 64, 67, 68]
Rye	*Secale cereale*	0.54–1.46	[47, 48, 53, 56, 60, 64, 69]
Millet	*Pennisetum* sp., *etc.*	0.18–1.67	[50, 55, 70, 75, 114]
Triticale	*Triticale secale*	0.50–1.89	[70, 71]
Wild rice	*Zizania* sp.	2.20	[53]

a) Depending on the data published.

Table 3. Content of phytic acid/phytate in legumes

Legumes Common names	Taxonomic names	Phytic acid/phytate[a] g/100 g (dw)	References
Kidney beans Haricot beans Pinto beans Navy beans Blackeye beans	*Phaseolus vulgaris*	0.61–2.38	[47–50, 53, 75–83]
Broad beans	*Vicia faba*	0.51–1.77	[79, 85–87, 100–105]
Peas	*Pisum sativum* var. *arvense*	0.22–1.22	[48, 65, 84–90]
Dry cowpeas Black-eyed peas	*Vigna unguiculata*	0.37–2.90	[48, 50, 55, 82, 91–98]
Chickpeas (Garbanzo/Bengal gram)	*Cicer arietinum*	0.28–1.60	[48, 50, 65, 83, 85, 86, 92, 95, 99]
Lentils	*Lens culinaris*	0.27–1.51	[50, 65, 82, 83, 86, 95, 106–111]

a) Depending on the data published.

[Source]

We do have many data on the effect of whole vs. refined grains, especially wheat, on the body composition of non-exercising individuals. As we'll discuss in more detail in the 'wheat belly' section, these data quite conclusively show no differential effects of whole vs. refined grains. Thus, anti-nutrients can't have a large impact on our gains. However, the theoretical potential for impaired protein absorption is much more relevant for strength trainees on high protein diets that want to maximize muscle protein balance.

Regardless of how much faith you put in the tentative anti-nutrient data or Nestlé's sponsored studies, you don't have to abolish grains from your diet to protect your gains. Some phytase can be produced in the human intestine to degrade some phytic acid, so you don't have to avoid all phytic acid. However, gut degradation is not nearly enough to fully counter the anti-nutrient's effects and there is also no capacity to adapt and upregulate degradation capacity in humans. You can also effectively compensate for anti-nutrients by simply eating more nutrients. However, anti-nutrients don't just affect the digestibility of the protein you eat, they also affect the protein already in your body. During digestion, a portion of the nitrogen and amino acids in your digestive tract originate from your own body's pool of amino acids. Normally, these amino acids are reabsorbed into the body, but anti-nutrients can inhibit this. As a result, amino acids are lost from your body. We currently only have relevant data on this in animals, so it remains speculative how much more protein and nutrients you'd have to consume to compensate for anti-nutrients. A simple way to think of anti-nutrients is that they're like a fractional multiplier of the nutrients, so only X% of the micronutrients in foods with a lot of anti-nutrients will be absorbed.

Our ancestors were aware of the problems with grains that modern humans seem to have forgotten, so they came up with ingenious cooking methods to reduce the anti-nutrient content of grains, namely fermentation, sprouting and soaking. Ezekiel and sourdough bread are some of the last remaining commercially available traditional grain products, but you can find many more in traditional communities. Compared to the bread you find in today's supermarkets, sourdough bread often has better mineral bioavailability, a lower glycemic index, higher anti-oxidant activity and better protein digestibility. Put simply, it's more nutritious and theoretically more biceps-friendly. Even people with Celiac disease can generally eat sourdough bread without issues, if it's properly fermented. However, there's very little research on if the theoretical health benefits of sourdough bread actually affect long-term health outcomes. The

fermentation time of sourdough bread does not seem to affect health biomarkers significantly. If you have no trouble digesting whole grains, traditionally preparing whole grains yourself may have a poor effort-to-reward.

➢ Guide

How to: traditional grain preparation

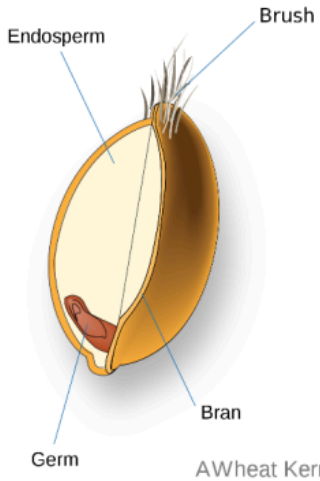
Wheat

In addition to the anti-nutrients, there are more concerns with wheat specifically than with other grains. The concerns are:

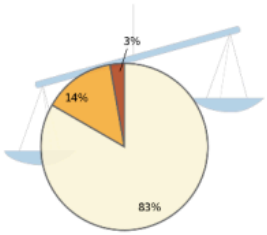
- Wheat amylase-trypsin inhibitors
- Lectins (WGA)
- Gluten
- Low-fermentable, poorly-absorbed, short-chain carbohydrates (= FODMAPs: fermentable, oligo-, di-, mono-saccharides and polyols.) We will discuss these in a separate section, as they're present in many other foods than grains.

These substances have given rise to the theories of 'leaky gut' and 'wheat belly'. Should you be concerned?

Wheat.



AWheat Kernel



Composition by Weight

	Carb./g	Protein/g	Fat/g	Fiber/g	Iron (% daily req.)	Others
Bran	63	16	3	43	59	vitamin Bs
Endosperm	79	7	0	4	7	
Germ	52	23	10	14	35	vitamin Bs omega-3/6 lipids

Nutritional Value (per 100g)

Gluten intolerance & celiac disease

Nutritionists used to think that gluten is perfectly fine for anyone except those with celiac disease: gluten allergy. Celiac disease is rare: it only affects about 1% of people. So wheat is often dismissed as something you don't have to worry about. However, throughout recent years a number of studies have convincingly demonstrated that many more people without full-blown celiac disease still have some form of intolerance to wheat. To quote a review by Catassi et al. (2013) on this topic: "While it is undisputable that in some cases the positive effect of gluten withdrawal can be explained by a placebo effect, this is not the case in true non-celiac gluten sensitivity (NCGS). In a double-blind randomized placebo-controlled study design, Biesiekierski *et al*. found that IBS-like symptoms of NCGS were more frequent in the gluten-treated group (68%) than in subjects on placebo (40%) [13]. Furthermore, a recent study found no significant differences between celiac disease and NCGS patients regarding

personality traits, level of somatization, quality of life, anxiety, and depressive symptoms. The somatization level was low in both diseases. Additionally, symptom increase after a gluten challenge was not related to personality in NCGS patients [17]."
Other double-blind placebo-controlled research confirms that gluten sensitivity is real: people with wheat intolerance experience objectively measurable increases in digestive symptoms after consuming wheat, even if they didn't know it. The main symptoms of wheat sensitivity are bloating, gas, mild stomach cramps and fatigue.

As with all subclinical problems, it's very hard to scientifically estimate how many people get digestive discomfort from consuming gluten that's not a nocebo effect. Prevalence rates for gluten sensitivity in research are very variable, all the way from 0.5% to 13%. Particularly many people diagnosed with irritable bowel syndrome (IBS) have gluten sensitivity.

The only thing that's still debatable is if it's gluten or the FODMAPs in wheat that mostly cause wheat sensitivity [2]. Many people with wheat or gluten sensitivity have an intolerance to many other FODMAPs as well, akin to IBS [2].

That said, most gluten sensitivity is a nocebo effect. Most people that say they have gluten intolerance, actually don't and many people can eat gluten without suffering any digestive symptoms, even some people with IBS [2, 3]. FODMAPs in general are more often problematic than gluten specifically. In some social circles, it has become a sign of sociocultural distinction not to eat wheat (which makes sense economically, as wheat is cheap), even when there's no need for health reasons to exclude wheat.

Wheat eating populations traditionally prepared their wheat by fermenting or sprouting it, creating breads like sourdough bread and Ezekiel bread. These methods not only eliminate many anti-nutrients [2, 3, 4], they also degrade the gluten [2] and FODMAPs

in wheat. Even people with true celiac disease can often eat traditionally prepared sourdough bread without issues. This suggests many cultures learned of the negative effects wheat can have on the gut from experience.

Moreover, modern wheat is not the same as the wheat glorified in the bible: “The selection of wheat varieties with higher gluten content has been a continuous process during the last 10,000 years, with changes dictated more by technological rather than nutritional reasons. Wheat varieties grown for thousands of years and mostly used for human nutrition up to the Middle Ages, such as *Triticum monococcum* and *T. dicoccum*, contain less of the highly toxic 33-mer gluten peptide [65].” (Source) As a result, the effect of ancient vs. modern wheat on your digestion is significantly different.

So how exactly could wheat harm your digestion?

Leaky gut

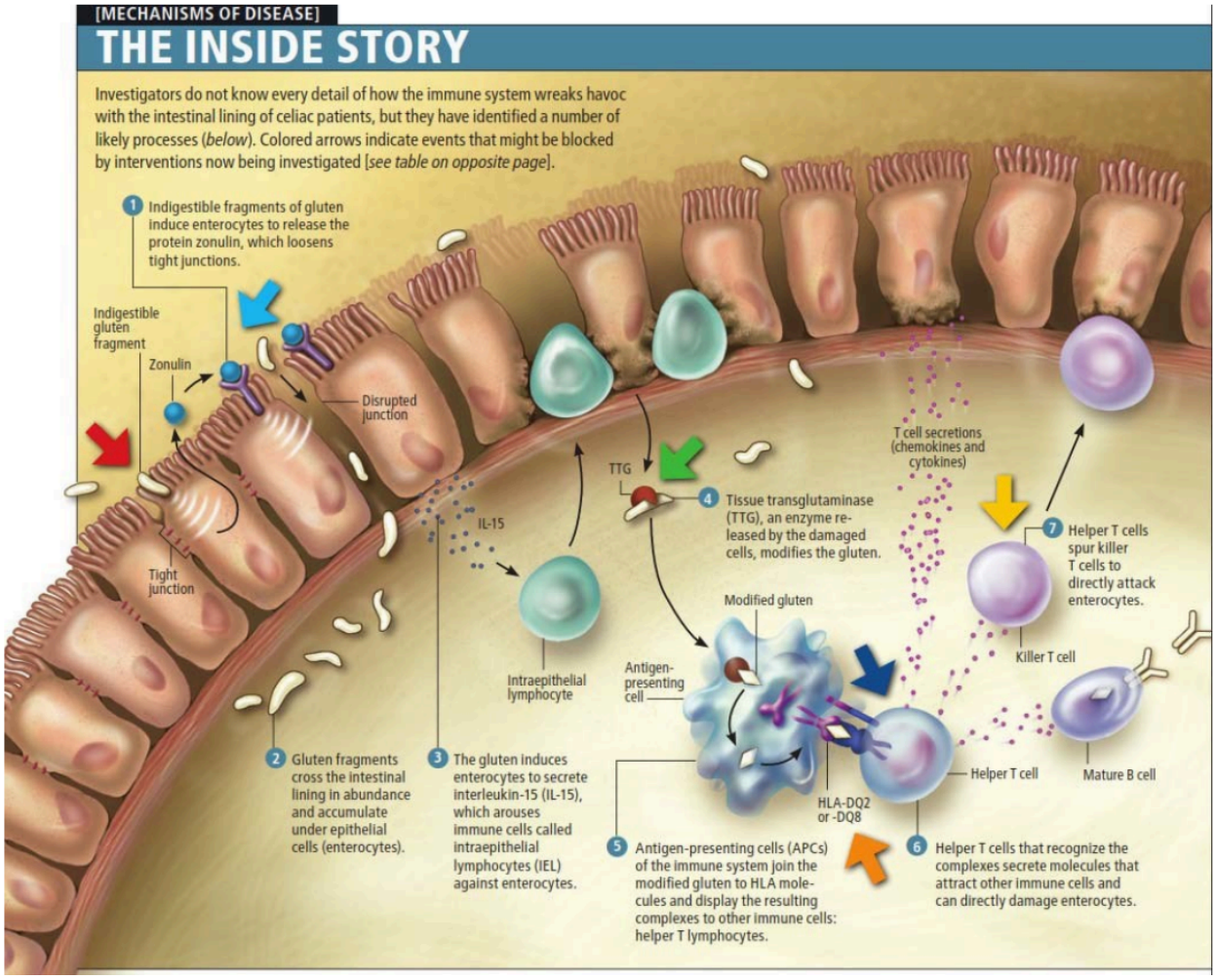
Gliadin, a component of gluten, increases intestinal permeability, more commonly known as ‘leaky gut’. In other words, gluten can cause your gut to leak slightly, whether you think you’re sensitive to gluten or not. The most definitive evidence comes from a study where the researchers cut out a piece of the intestines and tested how it responded to gluten in people who did and didn’t notice any reaction to 2 months of daily gluten consumption. All individuals experienced an increase in intestinal permeability after gliadin exposure, with greater permeability in individuals with gluten sensitivity or active Celiac disease.

Gluten’s damage to the lining of the gut is most severe in people with a deficient immune system and people with a bowel disorder, but an immune system response also occurs in healthy individuals without either disorder. Strength training also

increases intestinal permeability and associated digestive symptoms, so strength trainees may be at greater risk of leaky gut issues.

Leaky gut is not just a digestive concern: the digestive system can slightly but significantly impact energy expenditure, energy loss in stool, and nutrient partitioning [2]. In addition, a leaky gut can cause chronic inflammation, not only in the gut but also in the rest of your body, particularly your joints. In some research, markers of chronic, whole-body inflammation only increase in relation to whole grain intake in individuals with poor carb tolerance. Other research, however, has directly linked gluten intake to chronic inflammation even in people without celiac disease.

In contrast to the lines of evidence implicating wheat in inflammation and digestive disorders, some research finds a gluten-free may be bad for your gut microbiome. However, wheat is often substituted with gluten-free substitutes, which are basically pure processed flour, so this research mainly shows whole-grains are still generally better than processed grains, but it doesn't say anything about how whole grains compare to other, potentially healthier foods.



How gluten might damage your intestines and create inflammation (Scientific American, August 2009)

WGA

Another possibly problematic protein in wheat is wheat germ agglutinin (WGA). WGA is a lectin. “Lectins are present in a variety of plants, especially in seeds, where they serve as defense mechanisms against other plants and fungi. Because of their ability to bind to virtually all cell types and cause damage to several organs, lectins are widely recognized as anti-nutrients within food [36].” (Source) WGA can cause inflammation in human gut and immune cells and humans produce antibodies against WGA. The result

is that WGA can increase intestinal permeability and creates 'leaky gut'. However, unlike other lectins, wheat germ agglutinin activity can be almost entirely disabled by high temperatures. As such, WGA in baked/cooked wheat does not affect relevant health markers in human trials.

Wheat amylase-trypsin inhibitors

Wheat also contains wheat amylase-trypsin inhibitors (ATIs). ATIs interact with gliadin to cause an immune response and create inflammation in the gut. They may thus exacerbate the effects of gluten.

Wheat belly: does wheat hinder fat loss?

Many people anecdotally experience the phenomenon of 'wheat belly'. Consuming wheat makes them look fatter. It's easy to overeat on grains due to their high energy density, but research conclusively shows whole grains are no more fattening than other foods, calorie per calorie [2, 3, 4, 5, 6], and adding gluten to the diet does not affect body composition changes or resting energy expenditure in sedentary individuals. The likely reason for the 'wheat belly' appearance is bloating and abdominal distension from digestive problems caused by wheat in people that don't tolerate its FODMAPs, just like people with lactose intolerance often mistakenly believe dairy makes them fat.

Conclusion on wheat

Whole-wheat is reasonably healthy, but it comes with both benefits and problems for our gastrointestinal tract. The fiber and anti-oxidants in whole grains are protective against the inflammatory effect of gluten and WGA, so the overall net effect is generally neutral for whole grains in people without wheat sensitivity. However, since a non-trivial percentage of the population is wheat-sensitive to some degree, it's arguably worth testing for wheat sensitivity using an elimination diet and an oral food challenge, discussed later, to see if you feel better without wheat in your diet.

Traditionally prepared whole grains, such as sourdough bread, are significantly better, as they have almost none of the anti-nutrient or digestive problems that modern grains have. So if you consume a lot of grains, they should ideally be whole grains that are traditionally prepared with fermentation, sprouting or soaking to improve their digestibility. Alternatively, you can compensate for the anti-nutrients in whole grains by simply consuming more nutrients, in particular minerals and protein. A practical guideline can be to count only 50% of the protein and mineral content of grains towards your nutrient intake.

People with wheat sensitivity or IBS should generally avoid commercial grains entirely for the sake of their digestive health.

Refined grains should also generally be avoided or limited, as they are at best neutral in terms of health effects with practically no redeeming qualities.

Nuts

Much like legumes, there's little controversy about the health benefits of nuts, including almonds, walnuts and peanuts, though the latter are technically a legume. Study after study has demonstrated the positive health effects of eating nuts [2, 3, 4, 5, 6]. Nuts have many beneficial macro- and micronutrients and phytochemicals, including a fatty acid profile rich in mono-unsaturated fat, which is good for our blood lipids. A 2018 review of meta-analyses concluded nut consumption lowers LDL-cholesterol levels and improves endothelial function in intervention studies, which likely explains why epidemiological meta-analyses find nut consumption is associated with considerably reduced all-cause mortality, especially cardiovascular mortality.

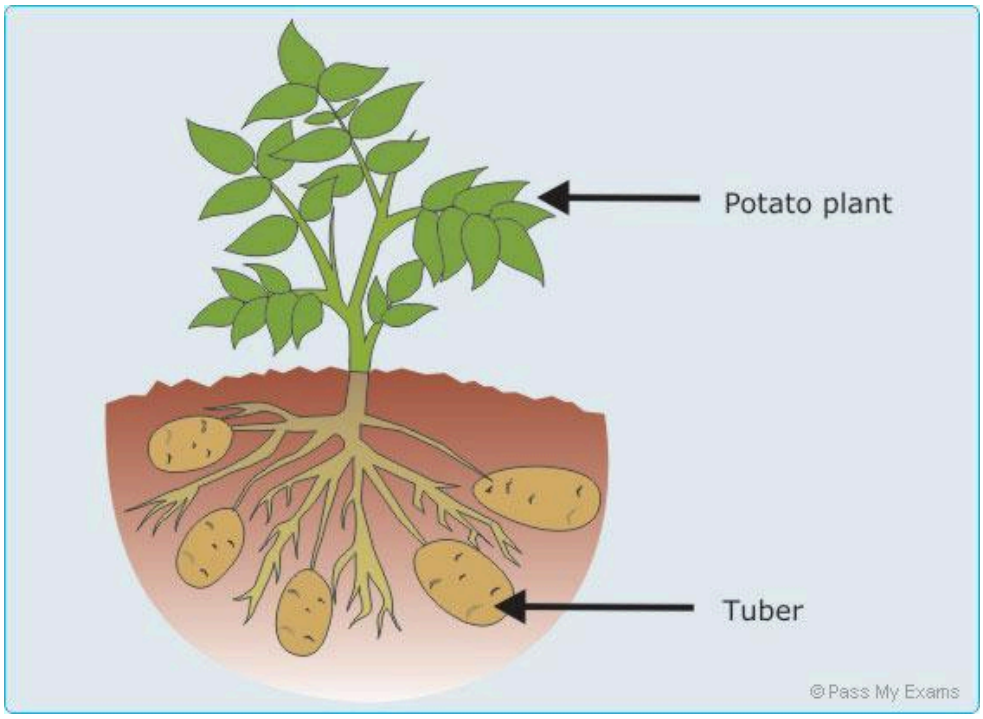
Nuts have a ton of calories, but they're not as net caloric as the label indicates. The energy in nuts is very difficult to harvest for the body, so your body excretes a significant portion of the energy without digesting or absorbing it. As you can see in the following table, nuts average about ~20% less metabolizable energy for your body than they contain. The low digestibility of nuts is likely related to their high amount of anti-nutrients. Boiling or roasting nuts significantly reduces their anti-nutrient content [2, 3]. In contrast to most legumes and grains, soaking or sprouting nuts does not considerably reduce phytic acid anti-nutrient levels or improve nutrient bioavailability, though it can still enhance total anti-oxidant capacity. Peanut oils and butters also have substantially higher digestibility than raw peanuts: only approximately 5% of their nuts are not digested, in contrast to approximately 18% for whole peanuts.

Study	Atwater energy factor estimate (kcal)	Actual observed net metabolized energy (kcal)	% Difference
Almonds			
Novotny et al. (2012)	605 (6 / g)	± 460 (4.6 / g)	32%
Peanuts			
Traoret et al. (2008)	± 631 (6.3 / g)	± 578 (5.8 / g)	9.1%
Levine & Silvis (1980)			~18%**
Walnuts			
Baer et al. (2015)	± 661 (6.6 / g)	± 521 (5.2 / g)	21%
Kranz et al. (2014)	± 653 (6.5 / g)	± 450 (4.5 / g)*	31%
Pistachio nuts			
Baer et al. (2012)	± 566 (5.7 / g)	± 540 (5.4 / g)	5%
Total average	± 622 (6.2 / g)	± 510 (5.1 / g)	19.6%

**: Displaced energy; **: based on fat excretion rate*

Tubers

Tubers are nutrient storage organs of plants, commonly found underground. They include potatoes, jams and cassava.



While commonly used more like grains because they're starchy, tubers are technically vegetables, root vegetables to be precise. Yet tubers don't have nearly the same positive track record in health sciences as other vegetables. A 2016 systematic review by Borch et al. and a 2018 meta-analysis by Schwingshackl et al. concluded potato consumption is not associated with chronic disease risk or all-cause mortality, positively or negatively. Few high-quality RCTs are available, but some data support beneficial reductions in blood pressure and improvements in gut health from potato consumption. Data on tubers other than potatoes is scant but points in similar directions and theoretically there's not much reason to expect major differences in health effects.

Potatoes are reasonably nutritious and fibrous when you factor in they're much less caloric than grains and they have some beneficial phytochemicals. Theoretically, you'd expect more positive health benefits from their consumption. The absence of this evidence may be due to the fact many people consume potatoes in highly processed form. The more you heat-process potatoes, the more fluid they lose and the greater their caloric density and the lower their nutrient density become. Removing the skin also removes much of their fiber content. French fries in particular are a notoriously unhealthy way to consume potatoes, if you can even still call them that.

Boiled, oven-baked or minimally pan-fried potatoes are safe, filling and nutritious, likely on par with whole grains but with greater satiety and less risk of gut problems, so they are healthy diet additions.

Soy products

Soybeans can be turned into a variety of foods, at least after cooking, as they are toxic in their raw form. The immature beans can be eaten in the form of green edamame beans. Soybeans can also be used to produce soymilk, soybean oil, soy protein or tofu, a common meat substitute, and they can be fermented to produce traditional tofu, tempeh, natto or miso.

Overall, soy products have net positive health effects according to a 2020 umbrella review of systematic reviews and meta-analyses of observational studies and randomized trials in humans, comparable to those of other beans. There is mixed evidence that soy products decrease total and LDL cholesterol levels and improve cardiovascular health.

However, most processed soy products aren't very nutritious anymore as a result of food processing. Moreover, their nutritional value is not as high as the label would have you believe, as like wheat, soy is very high in anti-nutrients like phytic acid. Because of its anti-nutrient activity, some research has found impairment of thyroid functioning resulting from soy consumption; however, the majority of evidence indicates soy products do not influence thyroid functioning.

Soy's anti-nutrients can be removed with fermentation, so traditionally fermented soy products are ok-ish protein sources and quite nutritious. Sprouted or soaked soybeans have reduced but not eliminated anti-nutrients as well.

Aside from the anti-nutrients, of particular relevance to strength athletes is that soy has phyto-estrogenic activity: certain plant compounds, like isoflavones, mimic the effects of female sex hormones, and function as selective estrogen receptor modulators

(SERMs). The consumption of soy has been linked to altered sex hormone functioning in both genders [2], including reduced estradiol levels in Asian women, alterations to the menstrual cycle, and reduced testosterone levels in men [2, 3], as well as rats. However, the magnitude of soy's hormonal effects in adult humans is often trivial and does not result in considerable health problems at regular intakes or increased risk of breast cancer [2]. Soy may even reduce the risk of certain gastrointestinal cancers, at least in women. A 2021 meta-analysis on men found no effect of soy intake on sex hormone levels. A 2009 meta-analysis on women also found no effect of soy consumption on estrogen levels; however, it did slightly increase the length of the menstrual cycle and it suppressed FSH and LH levels.

In conclusion, while it's not advisable to make soy a staple in your diet as a strength trainee, there is no reason to, say, avoid soy sauce because of the small amount of soy you'll consume. Traditionally fermented tempeh, natto, miso and tofu in particular are nutritious, safe and good for cardiovascular health in small amounts. Children and pregnant or breastfeeding women may want to limit soy consumption, however, due to the risk of hormonal side-effects.

Chocolate

Chocolate is often thought of as an unhealthy food, because it tastes good and resembles candy, at least when sweetened. Yet chocolate, actual dark chocolate with a very high cacao content, ideally 80% or more, provides significant health benefits. Cacao is rich in nutrients, particularly fiber and all essential minerals except sodium. Cacao also has many phytochemicals that make it a potent anti-oxidant and nitric oxide booster. Cacao flavanols have been shown to improve cardiovascular health by lowering blood pressure, blood sugar and LDL-cholesterol [2].

Cacao is high in saturated fat, which is part of the reason for its bad reputation, but again saturated fat is wrongly demonized here: cacao consumption decreases LDL and total cholesterol levels and may slightly raise HDL cholesterol levels [2, 3]. Moreover, cacao makes LDL more resistant to oxidation, thereby reducing inflammation. Cacao can also improve insulin sensitivity and lower blood sugar, thereby protecting us from inflammation.

Cacao also seems to have positive effects on the brain with mood enhancing properties. Multiple studies have found that dark chocolate consumption can improve people's mood and reduce depressive symptoms [2, 3]. More tentative research also suggests cognitive benefits and improvements in sleep quality.

However, note that most commercial 'chocolate' is primarily composed of sugar and oil or cacao butter. Virtually all the benefits of dark chocolate consumption seem to come from the cacao, so the darker the chocolate and the higher the cacao content, the healthier the chocolate. Still, despite the processed nature of most chocolate, multiple meta-analyses have found that (dark) chocolate consumption is associated with better cardiovascular health [1, 2, 3, 4]. Dark chocolate is highly caloric, but it seems to be

healthy if it has at least 70% cacao. Sometimes you can have your chocolate and eat it too.

If you're going to eat a lot of chocolate or especially cacao, beware of the caffeine content. Many people aren't aware chocolate has caffeine, but cacao can have a very high concentration of caffeine, ranging from an average 0.21% in commercial cacao to 0.6% for high-quality cacao [2, 3]. That can amount to the equivalent of 6 cups of coffee in 100 g cacao(!) You won't feel it as much generally due to the slower absorption over time though.

Sugar

Sugar is widely regarded as one of the most unhealthy foods, if you can even call it that. However, as you learned in the course module on dietary carbohydrates, practically all carbohydrates except dietary fiber have very similar metabolic effects. Thus, sugars and other carbohydrates have similar effects on our health when compared calorie for calorie in healthy individuals [2]. Diabetics and people with poor carb tolerance in general may be an exception and are generally best-off avoiding sugar.

The main problem with sugar is that it offers almost zero satiety, resulting in overeating and fat gain in ad libitum diet settings. The fat gain in turn is responsible for a wide array of negative health effects.

While sugar may not be inherently more fattening or unhealthy than other carbohydrates, sugar is still at-best a source of 'empty calories'. Sugar provides virtually zero nutritional value. Conventional sugar replacements like coconut sugar, honey, agave syrup or whatever's popular these days are all no better, as they're metabolically virtually identical. So while sugar may not be harmful, there is also absolutely no reason to consume it other than taste.

Sugar is also bad for your teeth and significantly increases your risk of caries.

To maintain an overall healthy diet, many health authorities recommend limiting sugar intake to no more than 5-10% of total energy intake. That's reasonable, but far more reasonable is to use low-calorie sweeteners and avoid sugars as much as possible so you can spend your calories on more nutritious foods.

Coffee

Coffee's health effects are hotly debated (no pun intended). While difficult to study experimentally because almost everyone drinks coffee and having people stop drinking coffee results in withdrawal symptoms, the totality of scientific evidence has come to the conclusion that filtered coffee is overall good for your health [2, 3]. Health benefits notably include better glycemic control, better cardiovascular health, including a small reduction in blood pressure if your blood pressure was normal to begin with, and a reduced risk of cancer. The health benefits primarily come from some of the enormous number of phytochemicals in coffee, notably its polyphenols that have anti-oxidant and anti-inflammatory effects. The health benefits of coffee thus probably overlap with those of other plants, notably vegetables.

However, unfiltered coffee can considerably raise your LDL-cholesterol and triglycerides [2, 3], because it contains high levels of the diterpenes kahweol and cafestol in the oil droplets and the sediment. These chemicals negatively affect our lipid protein metabolism. People that drink unfiltered coffee have shown considerably higher all-cause mortality, primarily due to cardiovascular disease, than people that drink filtered coffee. Still, unfiltered coffee drinkers had similar mortality as those that drink no coffee. Thus, it seems that the positive health effects of filtered coffee are on average cancelled out by the diterpenes in unfiltered coffee. For your health, it's best to drink paper-filtered coffee. Unfiltered coffee includes French press, Scandinavian boiled, Turkish, Greek and cafètiere (plunger pot) coffee. Many 'higher-end' coffee machines also don't use a filter, so at work and at restaurants there's a good chance your coffee is unfiltered. Fortunately, diterpenes are easily filtered out with a paper filter, so when you make coffee, use a paper filter. Instant coffee also generally doesn't contain many diterpenes anymore, even though it's often not strictly filtered.

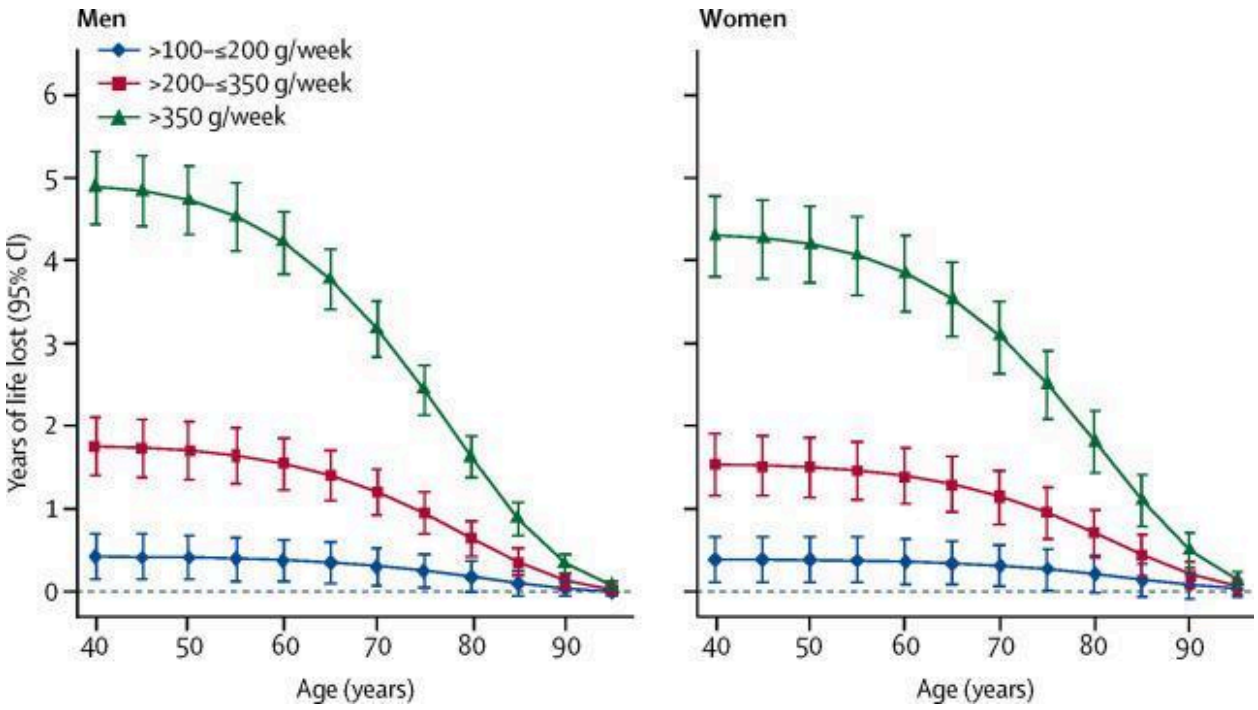
The caffeine in coffee does not seem to be responsible for its health effects, as decaffeinated and regular coffee have similar health effects [2, 3]. However, caffeine use has been linked to slightly increased blood pressure [2, 3], which can result in hypertension in individuals with already high blood pressure levels or high stress levels. Healthy individuals with normal blood pressure have little to fear from coffee consumption. There is also some research suggesting increased risk of pregnancy loss from caffeine use: see the module on sex-specific programming for more details on this. Therefore, when there is no particular reason to consume caffeine (see Supplements module), decaf coffee is preferred for optimal health.

Alcohol

Most people know binge drinking is bad for your health, but what about light drinking? Let's start with what that 'light' drinking means. By most official standards, more than 2 consumptions per day for men or 1 for women is binge drinking. So pretty much anyone that goes out partying engages in binge drinking.

Actual light drinking is the 'single glass of red wine' crowd. Research has had a hard time isolating the health effects of alcohol in this population, because like whole-grain wheat consumption, moderate alcohol consumption says a lot of things about someone's lifestyle. Someone that moderately drinks wine is more likely to be female, educated, of high socio-economic status and they tend to have above average self-control. Such positive associations make it difficult to find adverse effects of alcohol in associative studies. Another significant confounder when comparing light drinkers to abstainers is that the abstainer population includes former alcoholics and people that have given up on alcohol for health reasons.

Nevertheless, a large-scale 2018 meta-analysis of prospective studies and a 2023 meta-analysis of cohort studies found that truly moderate drinking is probably not a health concern but anything above this is. As you can see in the figure below, when you go over 350 g alcohol per week, which is the equivalent of 25 US consumptions per week, something a serious party goer may consume on a Saturday, you probably cut your life short by at least 5 years. Up to one consumption per day, there's almost no decrease in longevity, but above that, it's a dose-response risk. Note that there is no level of alcohol consumption that's net positive for your health.



Estimated future years of life lost by extent of reported baseline alcohol consumption compared with those who reported consuming >0–≤100 g per week. Source

Even if light drinking is not so bad for your physical health, it may not be ideal for your brain. A 2022 study by Daviet et al. found that "alcohol intake is negatively associated with global brain volume measures, regional gray matter volumes, and white matter microstructure […and] the negative associations between alcohol intake and brain macrostructure and microstructure are already apparent in individuals consuming an average of only one to two daily alcohol units, and become stronger as alcohol intake increases." Each alcoholic drink per day was roughly equivalent to the effect of aging 2 years. Similar findings were reported by Immonen et al. (2020).

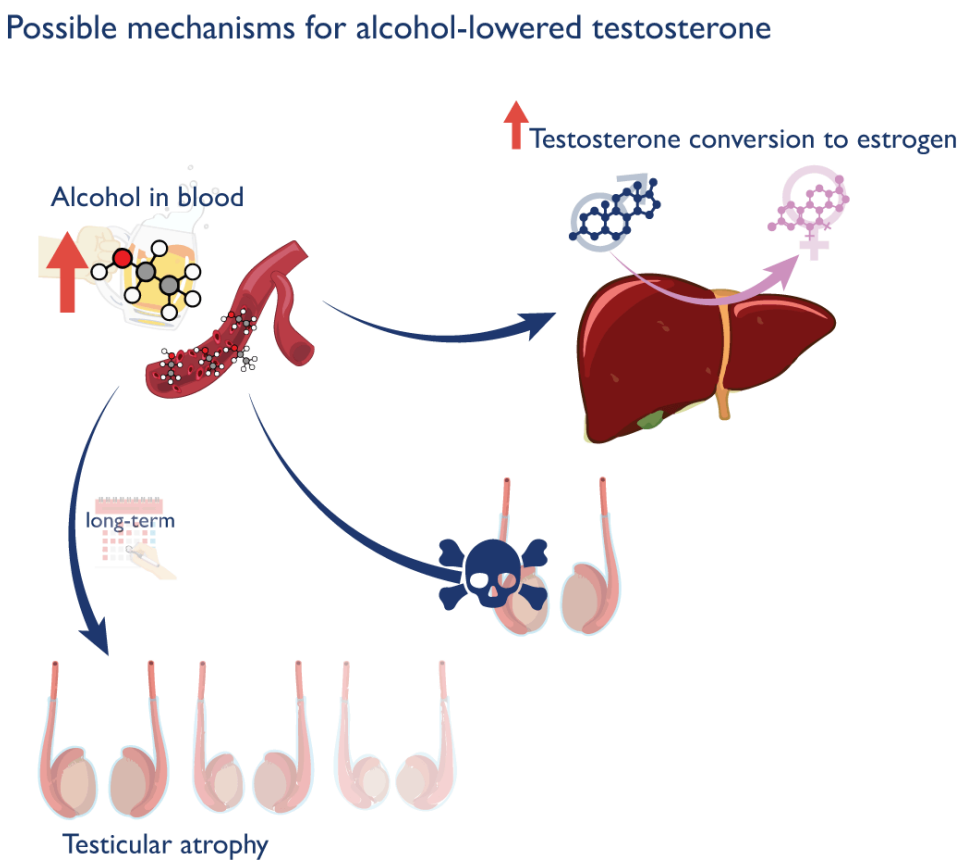
Alcohol intake also has a negative dose-response effect on sleep quality: the more you drink, the worse your sleep quality becomes [2, 3, 4]. Alcohol has hypnotic effects, so it can 'knock you out' and help you fall asleep, but it significantly reduces the quality of the sleep and its restorative effect.

Not all types of alcohol are equally damaging though. Wine and red wine in particular is associated with better health outcomes than other types of alcohol, likely due to its high anti-oxidant content that compensates for the negative effects of the alcohol. The most famous polyphenol in red wine is resveratrol, but it may also be one of the most overrated ones. Although some meta-analyses have found anti-inflammatory effects of resveratrol intake, those were often accompanied with fat loss, which is incredulous given the lack of mechanism by which resveratrol would cause fat loss. The latest 2024 meta-analysis of RCTs found no significant improvements in health biomarkers or body composition from resveratrol supplementation. Regardless of which polyphenols are responsible, wine consumption is associated with roughly neutral health outcomes, in contrast to the negative associations of other alcohol sources. A 2023 meta-analysis even found that wine drinkers had better cardiovascular health than non-wine drinkers. However, a 2022 systematic review of Mendelian randomization studies concluded wine consumption was not correlated with cardiovascular health outcomes or diabetes and even associated with higher all-cause mortality in the only study that measured this. Mendelian randomization (MR) is a method to estimate causality in observational studies based on genetic dispositions. This is a major advantage in the study of wine drinking, because wine drinking is associated with many other mostly positive lifestyle characteristics. Red wine is also not associated with the adverse brain changes seen in other alcohol drinkers. Campane et al. (2023) found no significant differences in brain structure between red wine drinkers and abstainers and a 2022 meta-analysis of longitudinal studies even found moderate wine drinking was associated with slower cognitive decline in the elderly. Interestingly, the latter meta-analysis found no significant differences between red and white wine.

Effects of alcohol on muscle growth

Unfortunately, alcohol is not good for men's testosterone levels. Alcohol, primarily, acetaldehyde, is directly toxic for the testosterone-producing Leydig cells in the testicles. (Yes, that's the balls.) In the long run, alcohol's toxicity might even cause a man's testicles to shrink, which directly reduces their capacity to produce testosterone. Also, chronic alcohol abuse may decrease the brain's signal to the testicles to produce testosterone [2].

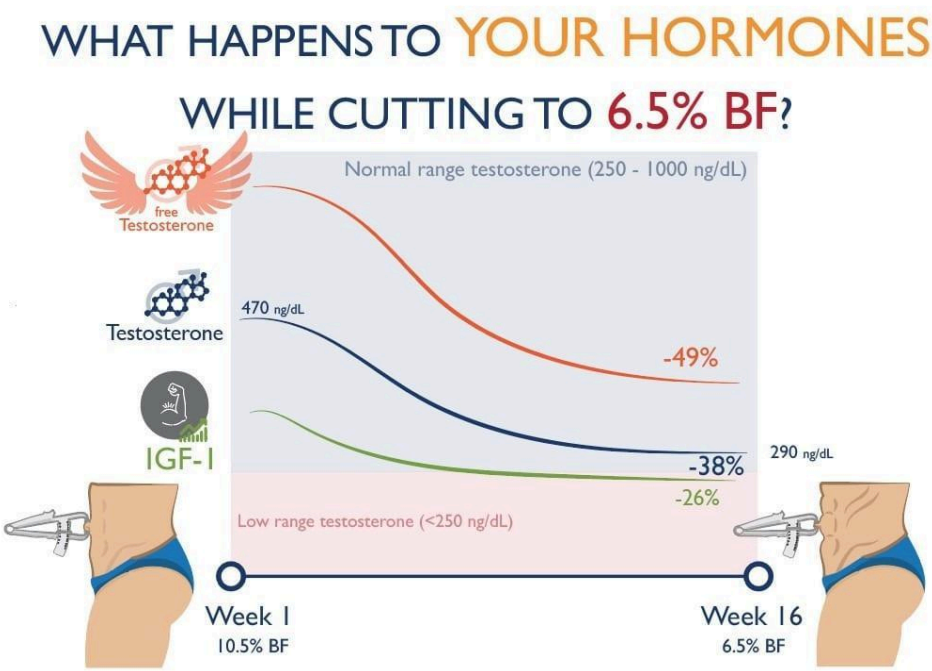
Alcohol can also increase the conversion of testosterone to estrogen in the liver [2], which leaves less of it in circulation.



If you're male, alcohol is toxic for your balls and can cause more of your testosterone to be converted into estrogen.

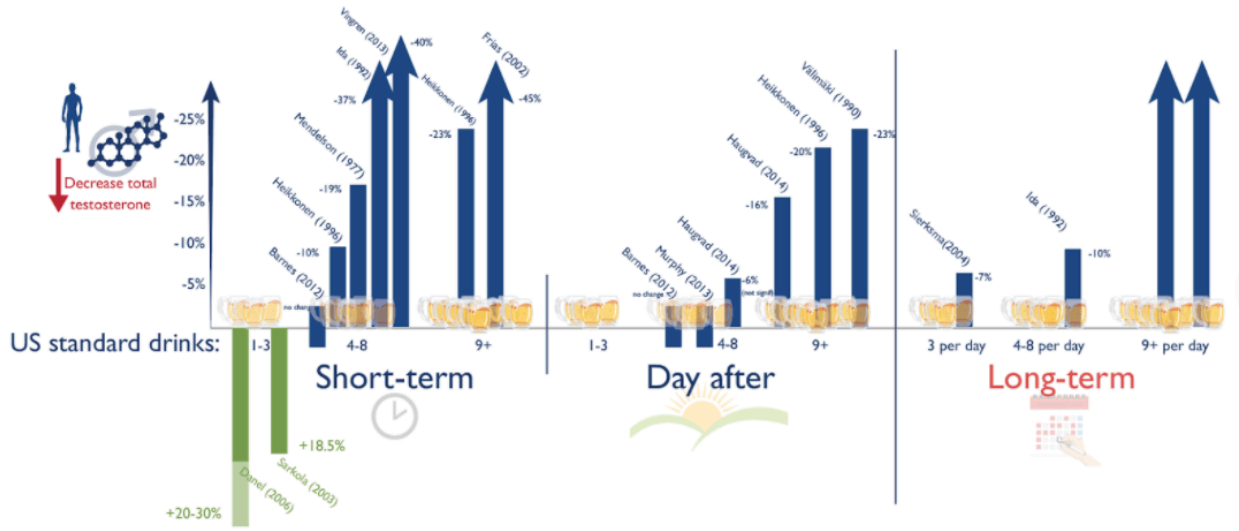
In contrast to what you'd expect based on the above effects, light drinking of around 1-3 US drinks **increases** testosterone levels in the hours thereafter [2]. However, before you start mixing your post-workout whey in whiskey, this is only a transient benefit, as the effect reverses over time with chronic consumption and higher doses of 4-8 drinks will lower testosterone levels by 18 to 40% [2, 3]. Your testosterone normally recovers within a day from this kind of cocktail party [2, 3].

If you get yucky with the boyz or girlz fo' real, the damage can be much worse. A drinking spree of 9+ US glasses of alcohol may instantly tank your testosterone levels by 45%. The next day there may still be a 23% dent in your manly hormones. This level of decrease in testosterone is comparable to being in contest prep for male natural bodybuilders: see the infographic below.



The acute effects are comparable to the chronic effects of daily alcohol consumption: see the following research summary. Up to a few drinks a day will have a small effect

on your hormones with a less than 10% decrease in testosterone. When you get into the double digits on a daily basis, testosterone levels drop by a considerable 25-55%, but it's safe to say you have more serious issues than your gains at this point. (If you do, you can seek treatment for addiction here.)



The negative effect of alcohol consumption on testosterone levels in men.

On a side note, if you love running to the bar after work: doing exhaustive cardio before binge drinking may further prolong the depressing effects on testosterone.

Alcohol can also impair growth hormone production.

A decrease in testosterone is obviously not desirable in general, but how exactly does this affect muscle growth? Testosterone tells your muscles to grow via the mTOR signaling pathway in your muscles [2]. Since alcohol decreases testosterone levels, it then shouldn't be a surprise that alcohol decreases mTOR kinase activity, a key enzyme that integrates signals for muscle growth [2, 3]. It then also shouldn't come as a surprise that muscle growth itself is impaired after alcohol consumption. Specifically,

9 servings of alcohol post-workout decrease myofibrillar protein synthesis (MPS) by 24%.

How bad is a 24% decrease in myofibrillar protein synthesis? As a reference, going from maintenance energy intake into a 40% energy deficit along with a 0.1 g/kg (0.05 g/lb) per day decrease in protein intake (1.3 g/kg [0.6 g/lb] vs. 1.2 g/kg [0.5 g/lb]) has been found to result in a 36% decrease in myofibrillar protein synthesis. So getting wasted on a night out probably has a comparable effect on your muscle growth as if you spent that day cutting.

Alcohol's effects on testosterone, mTOR and MPS are comparable to its effects on recovery after exercise but less bad, at least acutely. Light drinking up to 3 US consumptions doesn't seem to affect recovery from even very muscle-damaging exercise at all. At around 4 US consumptions we still see no consistent effects on strength recovery, but we do see the decrease in testosterone. Higher doses of 6 US servings of alcohol post-workout resulted in 11-19% worse strength decrements compared to drinking orange juice. Overall, alcohol's acute effects on recovery are surprisingly mild, but the long-term effects from impaired protein synthesis and hormone production are likely worse if you drink often.

In line with the mechanistic data, moderate consumption has little effect on long-term muscle growth in the only study we have on this topic, the BEER-HIIT study. Yes, that's actually the study's name. The researchers had a group of untrained men and women perform a 10-week bodyweight circuit training program. Half the participants consumed 2 alcoholic consumptions per day for men or 1 per day for women for 5 days a week. The other half consumed alcohol-free beer or sparkling water. Both groups experienced positive body recomposition, losing fat and gaining lean body mass, without significant differences between the groups. Moderate alcohol

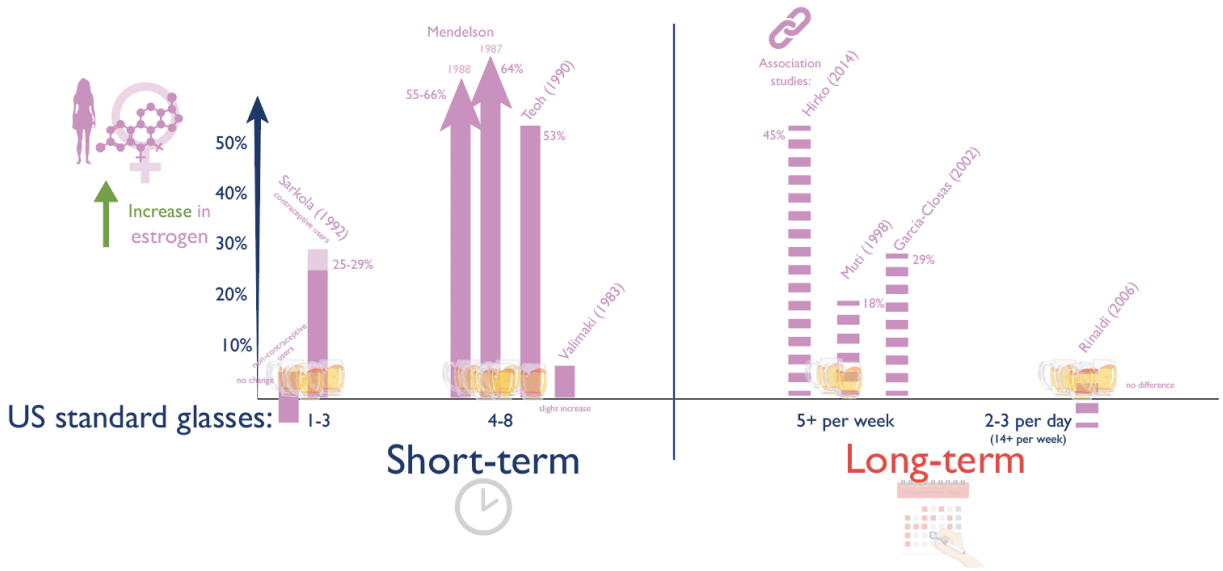
consumption thus didn't significantly impair muscle growth. The key word in that sentence is "moderate", not "didn't".

No balls, no problem?

Alcohol is commonly regarded as being just as bad for women as for men. However, the hormonal problems of alcohol in men all start because alcohol is toxic for the testes. Women don't have testes (citation needed?). So, why would alcohol be bad for women's hormones?

It's not. In fact, multiple studies show drinking alcohol increases testosterone in women [2, 3, 4] and drinking more alcohol is associated with higher overall testosterone levels.

Alcohol is also good for estrogen levels. And in contrast to common belief, estrogen is beneficial for muscle growth, especially in women. Light drinking doesn't have much effect, but 4-7 drinks can increase estrogen acutely by up to 66% [2, 3, 4, 5]. In the long term, drinking at least 5 glasses of alcohol per week is associated with higher overall estrogen levels in women [2, 3]. Other research finds it's testosterone rather than estrogen that's positively associated with drinking 2-3 glasses of alcohol per day. The following infographic summarizes the literature on the relation between alcohol consumption and estrogen levels.

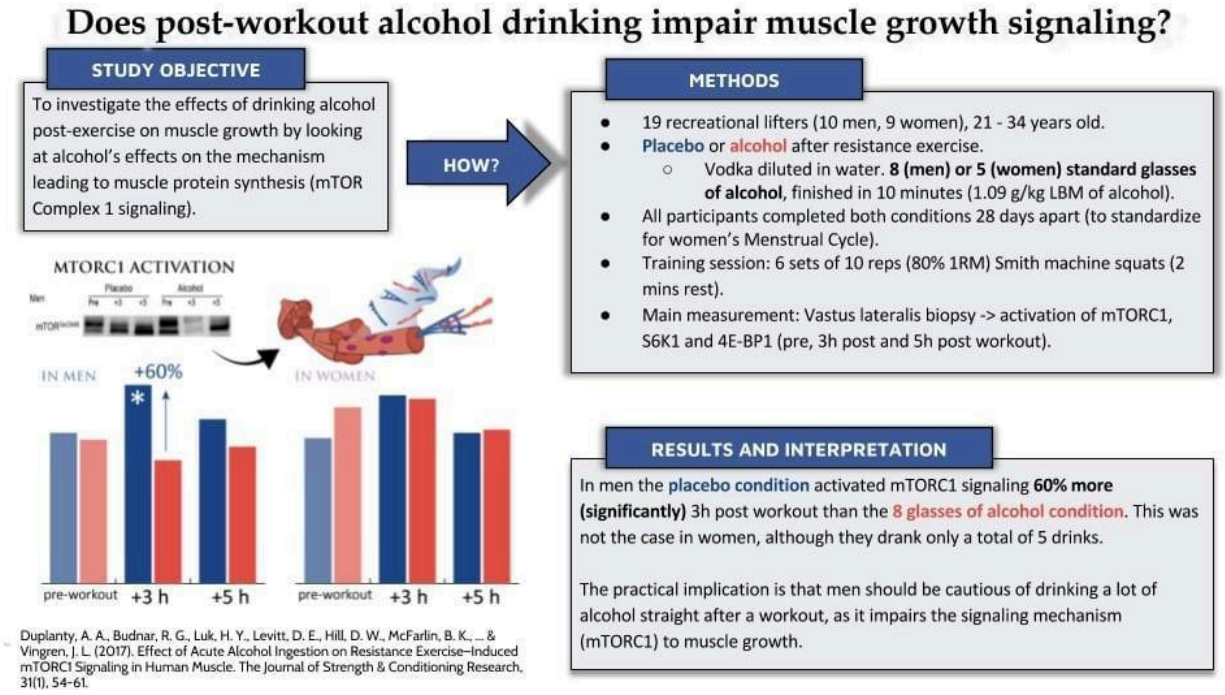


The effects of alcohol consumption on estrogen levels in women.

If this sounds too good to be true, there is a big caveat: these increases in sex hormone levels may be good for your gains, but they are related to liver toxicity that causes a disruption in hormonal metabolism. So they're not good effects in a healthy sense.

Since alcohol is actually good for testosterone and estrogen levels in women, does alcohol still reduce mTOR signaling for muscle growth?

Nope. As you can see in the infographic below, [several shots of vodka directly post-workout majorly decreased mTOR activation in men but not in women](#).



However, it's possible that muscle protein synthesis (MPS) is still hampered by alcohol in women due to negative effects downstream of mTOR, such as protein translation efficiency. Female rats suffer a decrease in MPS after acute alcohol consumption similar to male rats. However, chronic alcohol consumption only decreased muscle protein content and synthesis in male rats, not female rats.

Women also seem to have inherent protection against alcohol's detrimental effect on recovery after training. In contrast to men, up to 6 US servings of alcohol post-workout don't seem to affect the muscular recovery of women [2].

Conclusion

In men, alcohol reduces testosterone production because alcohol is toxic for the testicles. This effect corresponds to reduced anabolic signaling, muscle protein synthesis and muscular recovery. The damage greatly depends on the dose of alcohol you consumed. A single glass of wine will do basically zero damage. Up to a few drinks a day, the damage is still small, arguably trivial. A night out of partying will affect muscle growth similarly to if you were cutting in contest prep: while you can still make gains that day, it's much more difficult. The kind of night where you get completely wasted, end up at a stranger's house, get asked the next day if you're this person on YouTube and you have to watch the video on mute because even after taking 4 painkillers you can still hear yesterday's beat in your skull, that day is definitely wasted in terms of your gains. The next day probably won't be great either. Even then though, you can most likely still build muscle and strength the rest of the week.

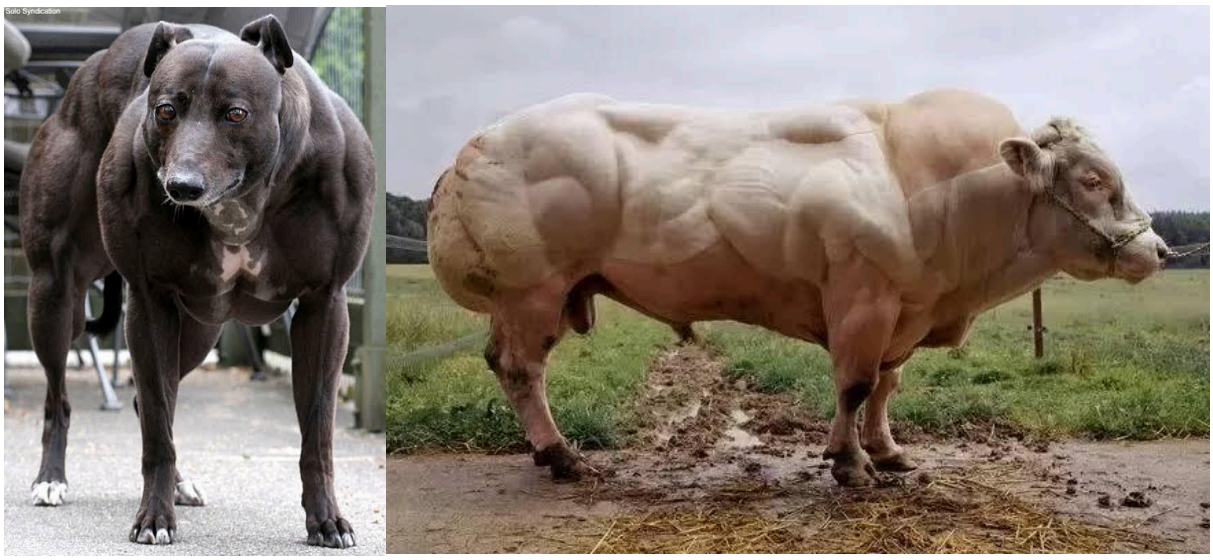
Women, by virtue of not having testicles, seem to be mostly exempt from alcohol's gain-robbing effects. Their testosterone and estrogen levels actually increase, there seems to be no reduction in anabolic signaling and muscular recovery seems to be unaffected even after hefty post-workout drinking. There might still be an acute decrease in muscle protein synthesis after binge drinking though due to a negative effect of alcohol on protein translation, but moderate long-term usage seems to be gain-friendly.

For how alcohol affects fat loss and how to minimize the damage of a night out, read our scientific guide to binge drinking.

Tobacco

No surprises here. Tobacco smoking is really, *really* bad for your health. As Dunga et al. (2015) summarized: “Tobacco smoking is still one of the most important risk factor for respiratory and cardiovascular diseases and an estimated 90% of causes of lung cancer are attributable to tobacco smoking and equally 90% of peripheral vascular disease in non-diabetic population is attributable to tobacco smoking […]”. The World Health Organization lists tobacco as the world’s greatest cause of preventable death.

Long-term tobacco smoking also impairs muscle protein synthesis and increases myostatin expression. Myostatin is a protein released by our muscles (a myokine) that limits muscle growth. It effectively functions as a brake for ‘excessive’ muscle growth. More myostatin expression thus likely reduces how muscular we can become. Myostatin inhibitors are currently being investigated as a means to circumvent our genetic muscular limitations. They’re not viable yet in humans, but some trials on other animals have found some success with myostatin inhibiting therapies, notably gene editing and myostatin blocking drugs. Some of these animals have become famous.



Animals with myostatin deficiency.

As you learned in the section on meat, burning almost any substance causes the formation of carcinogenic chemicals, and cigarette smoking has a particularly impressive list of cancer-causing chemicals in it, some of which are mildly radioactive. Add to this oxidants and free radicals and tobacco is the perfect recipe for your own funeral.

Nicotine does not appear to be responsible for tobacco's adverse health effects, not even its addictive properties directly. It's specifically the inhaled form of nicotine, in interaction with other compounds in tobacco like acetaldehyde, that's particularly addictive. Nicotine patches and gums aren't nearly as addictive, as we'll discuss in the Supplements module of the course.

Chewing tobacco is considerably less harmful than smoking tobacco, as it's the combustion of the tobacco that forms many unhealthy chemicals. Inhalation also causes far more rapid uptake of the chemicals than oral consumption. However, tobacco still contains inherently carcinogenic chemicals and chewing tobacco is associated with mouth and throat cancer, as well as higher cardiovascular disease risk. Dipping tobacco, like snuff, seems to be a bit safer still but still not without risk.

Since tobacco consumption of any kind is likely unhealthy to some extent but administering pure nicotine without tobacco has proven only moderately effective to help people quit smoking, scientists have come up with a tobacco-free smoking alternative: e-cigarettes. These electronic nicotine delivery devices are 'vaped' rather than smoked. These devices are made to look like cigarettes but contain nicotine, an aerosol and e-liquid with variable, relatively safe compounds rather than tobacco to form vapor rather than tobacco smoke. E-cigarettes are far safer than smoking tobacco but still contain known toxic and carcinogenic chemicals, so it's still uncertain how

risky they are [2, 3]. In the end, smoking anything involves inhaling a burned substance, so it's likely carcinogenic to some degree.

Health effects of food additives

Low calorie sweeteners

Artificial sweeteners and other high-intensity sweeteners, such as aspartame and sucralose (Splenda), are one of the most controversial topics in the fitness industry. They have been linked to neurotoxicity, cancer, disruption of satiety mechanisms and many more bad things. But is their reputation as satanic sugar deserved?

The answer is quite clear. Low-calorie sweeteners are generally not harmful. For the most commonly available and useful artificial sweeteners, aspartame and sucralose [2], in particular, there is an overwhelming amount of evidence establishing their safety for humans in non-extreme quantities [2, 3]. All controlled studies that find side-effects are in animals consuming more of the sweetener than any sane person ever would and then factoring in a 100-1000x safety margin.

Since they are devoid of calories, zero-calorie sweeteners do not raise blood sugar or insulin levels and consequently have no effect on insulin sensitivity [2, 3, 4, 5, 6, 7]. Stevia even seems to be beneficial for glycemic control.

Sweeteners also do not increase your appetite, though they may create a desire to eat when consumed in between meals, just like snacking does. It can psychologically result in ‘a taste for more’.

Artificial sweeteners can increase your preference for sweet foods, but all sweet foods can have this effect and sweeteners do not normally affect people’s food choices or energy intake.

While some epidemiological data seems to suggest artificial sweeteners cause weight gain, this relationship works the other way around. People that try to lose weight often use artificial sweeteners. In other words, overweight people often use artificial sweeteners to lose weight, as opposed to zero-calorie sweeteners causing fat gain (thermodynamics, anyone?).

So if you like to make your food sweeter, by all means use zero calorie sweeteners. They're akin to salt: a calorie-free way to increase the flavor of your food. With chili powder, salt and sucralose, you have 3 major tastes you can add to meals practically without calories.

Be warned though that most powdered sweeteners are not calorie-free. They rely on the bureaucratic gimmick that things with very low calorie counts per serving can be labeled calorie-free, while they still contain up to 3.9 kcal per gram from the bulk material, often maltodextrin. As such, with careful micro-dosing you're often better off purchasing pure sucralose powder or liquid sucralose to sweeten your food truly without calories.

Saccharin

A possible exception to the safety of zero calorie sweeteners is saccharin, a first-generation artificial sweetener first synthesized in 1879. Compared to sucralose and aspartame, there isn't as much research establishing its safety and one human pilot study by Suez et al. (2014) showed that saccharin consumption impairs gut health and induces glucose intolerance.

If you combine that with the fact saccharin is a coal tar derivative, it makes for good scare mongering. However, this was a pilot study with only 7 subjects, only 4 of them

developed glucose intolerance, there was no control group and the dosage was equivalent to consuming 5.6 cans of Cola Tab a day for a week. All other human research has found that saccharin consumption is completely safe, even for diabetics [2, 3, 4]. This includes a much better replication of the Suez et al. study by Serrano et al. (2021), in which consuming the maximum acceptable daily intake (ADI) of saccharin for 2 weeks did not affect gut microbiota composition or glucose tolerance in humans, nor in mice after 10 weeks of consuming 4 times the ADI. For reference, the ADI for an 80 kg person amounts to about 11 packets of Equal Saccharin.

So any remotely normal use of saccharin is probably safe. But since saccharin has a bitter, metallic aftertaste, it's generally a secondary choice compared to aspartame and especially sucralose anyway.

Erythritol

Erythritol is a sweetener worth mentioning specifically, since its texture is not too far off from conventional table sugar. This can be a major advantage over other sugar substitutes in dishes where you don't dissolve the sweetener. Erythritol can be used on pancakes, for example. Although erythritol is naturally present in some foods, it does not taste very natural and it has a cooling after-effect, like many sugar alcohols.

Erythritol.

Erythritol is a sugar alcohol that occurs naturally in fruit and certain fermented foods and can also be produced industrially via yeast fermentation of glucose. Despite it being 'natural', the body can only barely metabolize it, so it effectively only has 0.2 kcal per gram with 0 g net carbs.

The downside of its poor digestibility is that, like other sugar alcohols, it can be stressful for the gastrointestinal tract. Fortunately, most people tolerate erythritol much better than other sugar alcohols. The laxative threshold of erythritol is estimated at 0.80 g/kg (0.4 g/lb) body weight for females and 0.66 g/kg (0.3 g/lb) body weight for males, respectively [2]. Regardless, it's advisable to conservatively work your way up to that dosage if you want to consume that much in the first place, consuming erythritol mainly with/after meals and not exceeding dosages at which you experience any GI problems whatsoever. Your gut health may be harmed well before you notice diarrhea or other symptoms. Since erythritol isn't quite as sweet as sugar, many people like to combine it with another sweetener.

Other than its digestive issues, erythritol is very safe [2]. Toxicity is inherently prevented by the laxative issues that arise before any health damage occurs.

Allulose

Another new sweetener with a sugar-like texture is allulose. It also dissolves like sugar and can even be caramelized. Allulose is a naturally present sweetener in some fruits and it can be produced from regular table sugar. Allulose is chemically very similar to fructose. It's available in crystalized powder and syrup form. It's about 70% as sweet as sugar but only has a metabolizable energy density of 0.4 kcal/g with virtually no effect on blood sugar or insulin production. While we don't have nearly as many data on allulose as other sweeteners like sucralose, allulose has so far proven to be safe [2, 3].

If all of this sounds too good to be true, it is. The main problem with allulose is the same as with erythritol and most poorly-absorbed sugars: they result in diarrhea and other digestive side-effects in high doses. Most people are ok up to 0.4 g/kg (0.2 g/lb) per meal and 0.9 g/kg (0.4 g/lb) per day though, which can be enough for some purposes.

Practical application

All currently legally approved artificial sweeteners are perfectly safe when consumed below the maximum recommended intakes, which means most people needn't worry about them. Sucralose is arguably the best all-purpose sweetener for home use, as it tastes much like sugar, it's safe up to quite high intakes and it can be used in almost any type of dish. It does not have the texture of sugar though and since it's incredibly sweet, it cannot effectively be sprinkled on foods. If you want the texture of sugar, erythritol and especially allulose are worth trying.

➢ Recommended reading

Is aspartame safe?

Are artificial sweeteners bad for your gut bacteria?

MSG

Monosodium glutamate (MSG) is a flavor enhancing food additive that's particularly popular in Chinese cuisine for its umami taste. Just like low-calorie sweeteners, MSG has garnered a poor reputation as a food additive. While it has a chemical sounding name, MSG is merely the combination of water, sodium – the same you find in table salt but in much lower amounts – and glutamate, a non-essential amino acid that occurs in many natural foods in much larger amounts than any sane person would consume in the form of MSG. MSG can be extracted from seaweed or produced by natural fermentation of molasses made from sugary food items like cane sugar.

Unsurprisingly given its harmless composition, there is widespread scientific consensus that MSG is safe for human consumption [2], even without any practical upper limit. While you can find many terrifying anecdotes about the evils of MSG online, multiple scientific studies have shown that even people with self-proclaimed MSG sensitivity do not experience any side-effects in double-blinded experiments, or they experience them without consuming MSG. In other words, 'Chinese restaurant syndrome' and other myths about MSG are nocebo effects, entirely psychosomatic.

Note that glutamate only has its distinct umami flavoring effect in its free form, not when it's combined in proteins like you normally find it in high-protein foods.

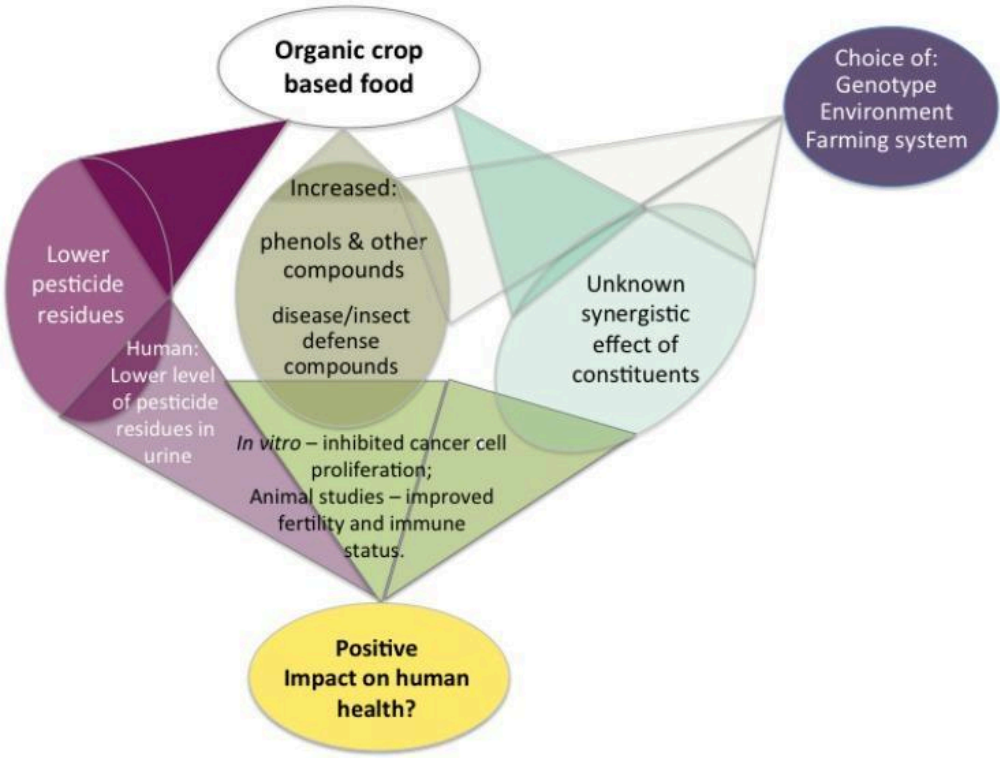
Health effects of food preparation methods

Organic food

The definition of ‘organic’ food is generally that it does not contain any artificial or synthetic compounds, like hormones, antibiotics or genetically modified organisms. Regulatory laws vary per country, however, and ‘organic’ does not always mean ‘100% organic’.

Organic food differs from conventionally produced food in several ways.

- It is generally far more expensive to produce because many methods to increase food yield, like cheap synthetic pesticides that prevent bugs from eating the food, are not allowed.
- Organic food contains fewer toxic compounds, like pesticide residues, but the difference is generally too small to have significant health effects.
- Organic food tends to contain more micronutrients, anti-oxidants and beneficial chemicals. However, the variation in nutrient content due to farming conditions and the environment are significantly larger than the difference between organic and non-organic food. The overall difference in nutritional value between organic and conventional food is small, arguably trivial.
- Organic animal food tends to have a slightly more favorable macronutrient composition with more protein and a more beneficial fatty acid composition, including a better omega-3 to -6 ratio [2, 3].



So how does organic food affect our health? Animal research finds significantly positive health effects of organic food compared to conventional food, but the majority of controlled human research finds no significant beneficial health effects of organic food [2], though we can't really expect it to for 2 reasons.

- Most study durations are very short, generally 2-4 weeks, whereas health effects like poisoning from heavy metals or chemicals may take years to manifest.
- Many studies incorporate only a single or at best a few organic foods in a diet that is still mostly industrially prepared.

Observational research finds far more significant health benefits of long-term organic food consumption, including higher fertility and a slightly lower risk of cancer. However, observational research is strongly confounded by the fact consumers of organic food also consume overall healthier food choices with fewer processed foods, and they are

generally more health conscious and more physically active. This makes it very difficult to ascertain if their superior health is a result of their organic food consumption or any of the numerous other things they do more for their health than the average person.

All in all, the health benefits of organic food appear to be very modest. Your food choices are far more important than whether those foods are organic or not. Organic junk food still pales in comparison to most whole foods in terms of nutritional value.

Local food

More important than whether the food was produced organically may be whether the food is from a local source. Despite many grocery stores promoting their fruits and vegetables as 'fresh', this is often simply a blatant lie. Many foods you see in Western supermarkets are imported from less developed countries, where they can be produced much more cheaply. When the tomato is 'fresh' in the supermarket, it may have already been refrigerated and kept out of the sun for a week, or in fact several months for less perishable foods.

As plants are deprived of sunlight and disconnected from their origin plant or roots, they generally start losing nutritional value. How big is the difference between truly fresh (preharvest) plants and the plants we buy in Western supermarkets? Most research is on vitamin C and there we can see the difference can be major, with multiple studies finding vitamin C losses in fruits and vegetables as high as 50% from preharvest to supermarket condition [2, 3]. Chard can also lose much of its vitamin C content when stored.

However, vitamin C content is particularly susceptible to degradation, because vitamin C is a water-soluble vitamin that's produced in plants under a strong influence of

sunlight. Other nutrients, especially minerals, are likely not as easily lost from the plant or animal. In spinach, flavonoid content doesn't change significantly when properly packaged and stored, yet total antioxidant activity does decrease.

The food in question also matters greatly. Some types of potatoes increase in vitamin C content while ripening in storage conditions. Potatoes grow underground, so cold and dark storage conditions are native to them.

Overall, whether food is produced locally or imported from afar is unlikely to make or break your diet. Vitamin C is not a micronutrient you should risk deficiency in if your diet's any good and for other nutrients, it's unclear how detrimental prolonged storage is for its nutrient content. If you can easily buy local food for an affordable price, that's great, but in practice, you often don't know how fresh food truly is, how it's been stored or what species it is precisely. Locally produced food can also be hard to find.

Summary

'Organic' does not mean as much as many consumers believe. Organic foods generally have lower amounts of toxic compounds, more anti-oxidants and more nutrients, but the difference in terms of actual health effects seems to be small.

What is more important for your health than whether the food is organic is if the food is fresh, how it has been processed and, for animal products and fat sources in particular, what the animal ate.

Given that organic food is generally considerably more expensive than non-organic food, the cost-benefit of buying organic for your health is generally low and you should

first consider your overall food selection. For example, the cost-efficiency of switching from beef to fish is generally far better than switching to organic beef.

The health benefit of organic food is often greatest for fatty animal products, like eggs, fatty meat and whole milk, so these foods are the first to consider purchasing from organic origin. Here too what the animals ate is most important, so, for example, you're generally better off eating conventional eggs from flaxseed fed chickens ('omega-3 eggs') than organic eggs from chickens fed organic wheat.

You may of course also prefer to buy organic food for ethical reasons. This course is restricted to objective considerations, so we won't go into philosophical considerations.

GMOs

Genetically modified organisms (GMOs) are organisms – including plants, bacteria and animals – that have been subject to genetic engineering. Genetic engineering techniques include knocking out genes, silencing genes, inserting genes from one organism into another. Selective mating techniques do not fall under genetic engineering.

People often fear what they do not understand, so like sweeteners, MSG and nuclear energy, GMOs have a poor reputation among the general public. However, in the scientific community there is widespread consensus that currently commercially used GMOs are very safe [2, 3, 4]. Whether an organism has a gene because its parents had it, because of a natural genetic mutation or because it was inserted in a lab has no inherent effect on its functioning, just like vitamin C in a pill inherently functions just like vitamin C from food in the body.

Heat processing & cooking

Heat processing your foods, including cooking, generally reduces the food's nutritional content [2]. Water-soluble vitamins are particularly prone to being lost during heat processing, as they are lost along with the water in the food. As much as half of a plant's vitamin C content can be lost when it's boiled. However, if your diet's any good, you shouldn't be at much risk of deficiencies in water-soluble vitamins (caveat: vegetarians should pay attention to vitamin B deficiencies).

On the plus side, cooking often also improves the bioavailability of the food by destroying anti-nutrients and making it easier for the body to digest and absorb the nutrients, often including protein, rendering the overall change in the nutritional value of the food net positive in many cases. Many plants and meats pose significant digestive and anti-nutrient problems when consumed raw, whereas they're completely fine when cooked. For example, *Brassica* AKA cruciferous vegetables such as broccoli have a significant amounts of goitrogens, substances that interfere with thyroid functioning and may cause goiter. However, most goitrogens are destroyed during cooking, generally rendering these foods safe for human consumption: they're in fact some of the healthiest foods on the planet.

Overall, most conventional cooking practices are fine. This includes grilling, stir frying, boiling, broiling, simmering, poaching, roasting, baking, sautéing and steaming.

Microwaving

Microwaves heat food by emitting electromagnetic waves into the food. While many people intuitively fear such artificial food preparation methods, microwaving food preserves the nutritional value of most foods just as well as the conventional cooking methods listed above [2]. Microwaving effectively retains most nutrients by virtue of its

short heating period with relatively low fluid losses. The radiation levels from a microwave are not nearly high enough to cause health problems in humans, so microwaving is a very healthy cooking method.

Deep frying

A very important exception to the general acceptability of heat processing is deep frying. The intense, prolonged heat produced during deep frying can result in the formation of toxic and carcinogenic substances. While deep frying per se is not always problematic for our health, it is when you deep fry polyunsaturated fats (PUFAs), and unfortunately most restaurants use PUFA-rich oils for deep frying. Polyunsaturated fats exposed to the heat of deep frying form trans fatty acids, which are notoriously unhealthy (see module on dietary fat). Artificial trans fatty acids can distort cell membranes and their consumption is associated with serious brain and heart toxicity, including coronary heart disease, depression and Alzheimer's disease [2]. Deep frying also destroys most omega-3 fatty acids. If you value your health, it's best to completely avoid consuming any artificial trans fats. Many countries have strict restrictions on the artificial trans fat content of supermarket foods, but restaurants have much more leeway with how they produce their foods.

Fortunately, regular baking and stir frying do not result in the formation of trans fat.

Open flames

Barbequing and other open flame grilling techniques are another problematic food preparation method, especially when they charcoal (blacken) a food. When you expose any substance directly to flames, you're effectively burning it and burning food can form many carcinogenic compounds [2], increasing your risk of cancer when you

consume them. Barbequing fatty foods is particularly unhealthy, because when the fat drippings fall on the flames, they form many toxic and carcinogenic substances.

Freezing

Freezing tends to have little impact on the nutritional value of food and is widely accepted to be safe. Frozen plant foods – e.g. fruit and vegetables – are often actually riper than 'fresh' plants, as the latter have been picked days or weeks ago before they were fully ripe to account for the transportation process. (See the section on organic food for the relevance of purchasing local food.) As such, buying frozen food is generally an excellent way to save money on whole foods and not a concern for your health.

➢ Recommended reading

Fresh vs. frozen fruit and vegetables – which are healthier?

Juicing

No, this isn't about steroids. We're talking about fruit and vegetable juices. Blending vegetables is a very easy way to consume a lot of them. In theory, that is. In practice, to make veggie shakes palatable, you often need lots of fruit or carrots and you're left with a low proportion of the veggies you otherwise wouldn't consume, like, say, spinach. Zero calorie sweeteners and protein powder can help a lot, but not many successful dieters end up incorporating veggie or fruit juices into their diet long-term.

The easier consumption of fruits and veggies in shake form is also their main downside for most individuals. A primary reason to consume fruits and veggies is because they're very satiating for their low calorie content, making them great fat loss foods. However, blending them into a juice majorly reduces their satiety index (see ad libitum dieting topic for more details). If you consume the pulp, which has most of the fiber, you don't lose out on any significant health benefits, but you do lose the satiating effect. As a result, vegetable juices are generally only convenient when bulking at such high energy intakes that it otherwise becomes problematic to get your veggies in.

➢ Recommended reading

Juicing: good or bad?

General conclusion

In practice, how you prepare your food doesn't matter much and it's a minor consideration in comparison to taste or finances. People sometimes obsess over these minutiae and lose track of the bigger picture: it's much healthier to consume a lot of frozen-then-cooked-and-juiced vegetables than to eat raw vegetables but fail to eat

enough of them in the first place. Similarly, it's generally better to eat enough frozen or canned fish than to not eat fish in the first place.

A notable exception is intense heat processing of polyunsaturated fat, which results in the formation of trans fat. It is therefore advisable to strictly avoid all deep fried, hardened or partially hydrogenated oils with a significant polyunsaturated fat content, particularly vegetable oils.

Detox diets

Detox diets are all the hype these days, but there are a few misconceptions the fundamental principle of ‘detoxing’. For one, in contrast to lay wisdom, it's not the case that some things are toxic and others are not. In toxicology, a basic principle is "The dose makes the poison." For example, if you consume tons of water, you get water poisoning/toxicity. So each and every one of us is in fact loaded with substances that can become toxic in greater quantities.

Secondly, your body is very good at detoxing itself. Your liver and kidneys are working around the clock to metabolize or excrete potentially harmful substances from your body.

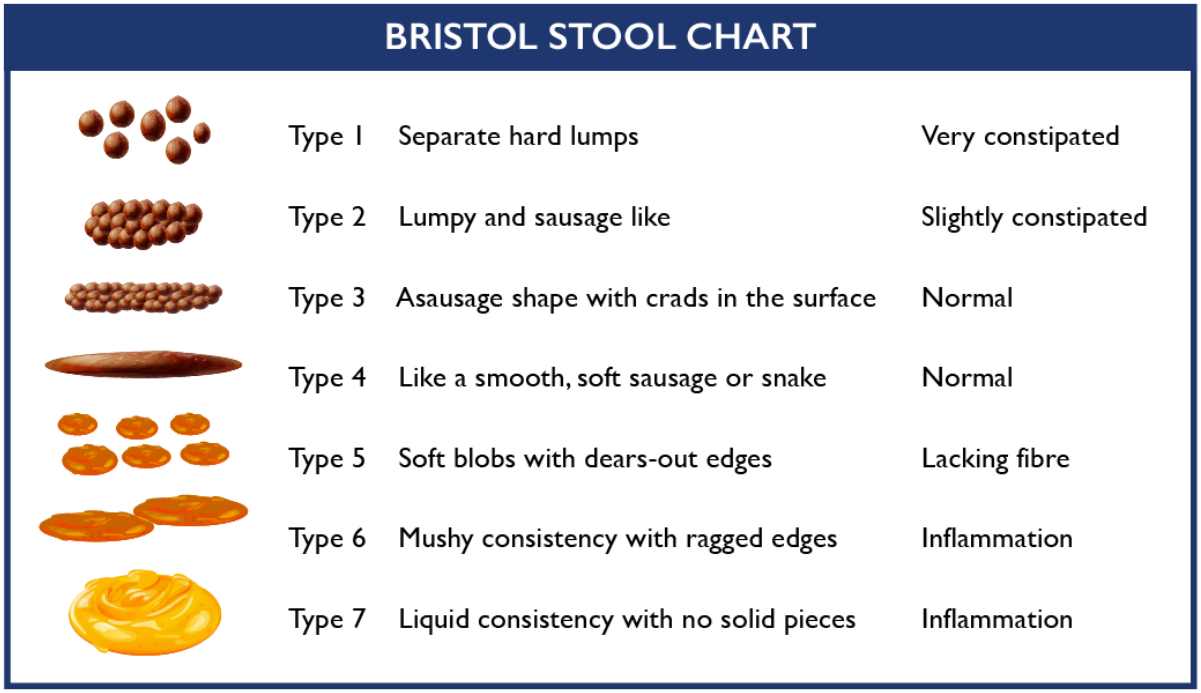
The basic conclusion here is that the best 'detox diet' for a generally healthy person is just a regular 'healthy diet'. You don't need water fasting or liters of tomato juice or any other such extreme fad diet we see these days. To quote a recent research review on this topic: "Although the detox industry is booming, there is very little clinical evidence to support the use of these diets."

FODMAPs, IBS & digestive health

Irritable Bowel Syndrome (IBS) has silently become a common issue in the general population. Much like it has become commonly accepted that everyone gets a cold or illness at least once a season, constipation and digestive issues have become common to the point that many people take them for granted as something that just happens sometimes. The diagnosis of IBS exemplifies the issue: it's a rather idiopathic diagnosis by exclusion, basically meaning: "You have digestive issues, but we don't really know why." Researchers estimate that up to 20% of the western population suffers from some form of GI distress. Only a tiny fraction (15%) of people with symptoms actually seek medical attention, but this still accounts for nearly 50% of visits to gastroenterologists and physicians. The need for effective treatment has never been higher, since digestive issues can affect work productivity, lead to social isolation and even foster higher rates of absenteeism.

IBS is also linked to disruption of the gut-brain axis, the immune system and the enteroendocrine (related to hormones in the gut) systems, as well as excessive intestinal permeability. Thereby, digestive problems can easily affect other parts of the body.

As a reference to diagnose whether you're constipated, you can use the Bristol stool scale.



The authors certainly had a way with words...

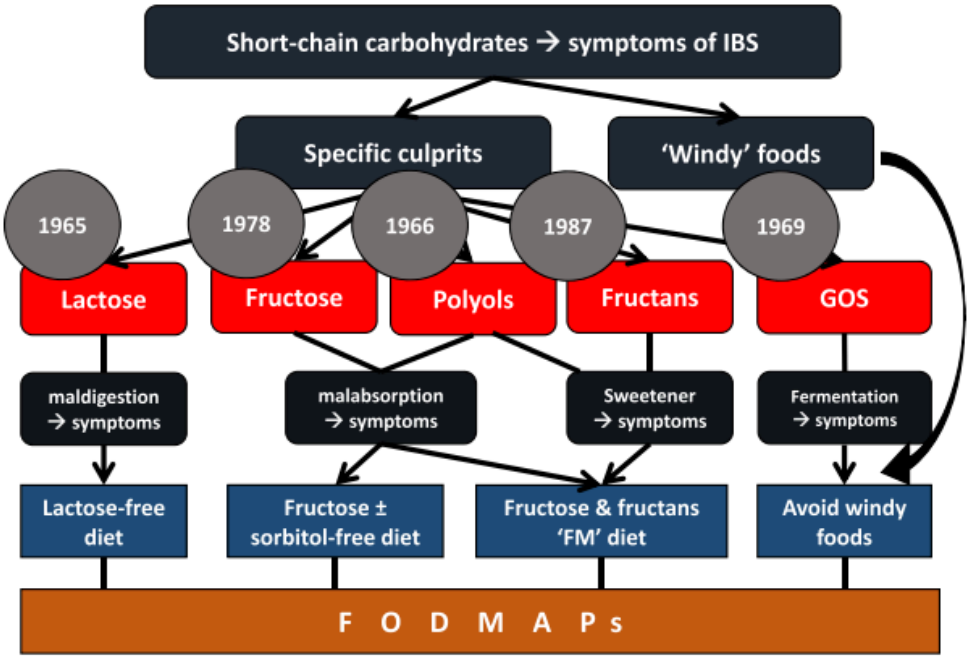
Causes

Via the gut-brain axis, psychological stress can also cause IBS symptoms [2, 3]. Stress and cortisol effectively shut down digestion, exacerbating many digestive problems.

However, diet is generally considered to be the most important factor for digestive health. The idea that certain food can trigger gastrointestinal symptoms is nothing new to many people. 60-80% of patients with IBS believe that their symptoms are diet-related [2]. Practitioners that work with clients estimate 2-20% of people have significant food intolerances: “whether due to a placebo effect, secondary benefit, or as a biophysical result of excluding a food from the diet, [general practitioners] acknowledged both personal and therapeutic benefit in working with the patients' belief in food intolerance and with behaviours associated with the beliefs.” Some blame

dairy products; others single out things like fruits, grains, vegetables and legumes. These foods are often avoided if the consumer experiences excessive flatulence, bloating and discomfort in their gut. In IBS patients, 50% of each person's pain episodes worsen within 90 min after eating. A lengthy line of research may have found some answers to why certain food causes these symptoms.

In 2004, a research group in Australia noted that these foods contained Fermentable Oligosaccharides, Disaccharides, Monosaccharides and Polyols. They coined this collective group of carbohydrates FODMAPs. The graphic below depicts how researchers have singled out each of these distinct groups over the course of the past 5-6 decades.



Source

If you have any problems with your digestion, it is advisable to test for FODMAP intolerances. Most people have some degree of intolerance to certain FODMAPs.

The first study about a diet that specifically eliminated FODMAPs came back in 2005. Since then, low FODMAP diets have become commonplace among people with gastrointestinal problems. Up to 70-75% of patients with IBS respond well to this diet [2], compared to 25-50% responding favorably to control diets. Low-FODMAP diets significantly improve IBS symptoms (bloating, abdominal pain, flatulence, diarrhea, nausea and constipation), energy, quality of life and colonic health [3, 4, 5] as supported by multiple meta-analyses [1, 2, 3, 4, 5].

Probiotic consumption can also significantly reduce IBS symptoms. Along with probiotics, low FODMAP diets are currently the most established nutritional interventions for people with IBS.

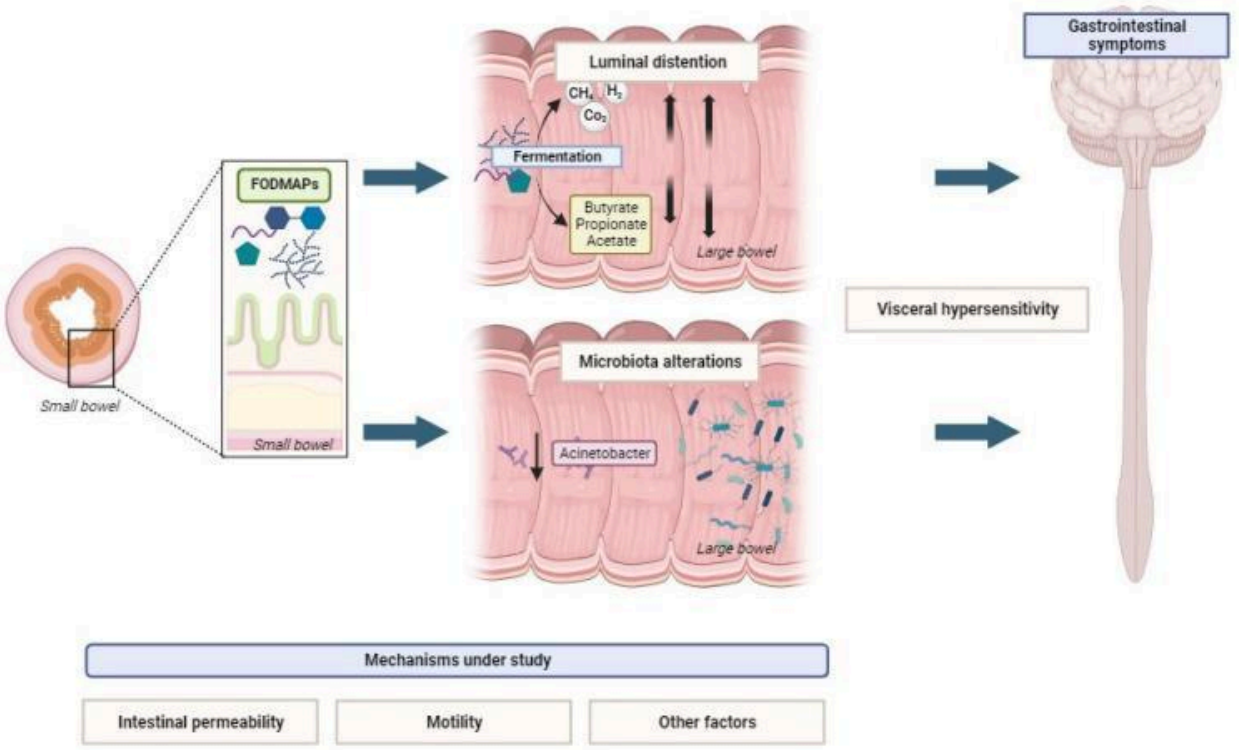
IBS-like symptoms are also present in over 30% of inflammatory bowel disease (IBD) patients. Since low-FODMAP diets improve these symptoms, the diet could likely benefit those patients as well. However, undernutrition is common in IBD, so the diet should be supervised by a dietitian.

Why are FODMAPs problematic?

The name stands for 'Fermentable Oligosaccharides, Disaccharides, Monosaccharides and Polyols'. Basically, FODMAPs are carbohydrates that many humans can't digest well. There are several categories of FODMAPs.

- Oligosaccharides, which contain galactooligosaccharides (GOS) and fructans. Humans lack the enzyme to hydrolyze GOS. It therefore rapidly ferments and forms a lot of gas.
- Fructans are fructose units; most fructans come from inulin and contain fructooligosaccharides (FOS). Humans lack the enzyme to digest fructans, so more than 90% of goes to the large intestine where it ferments.

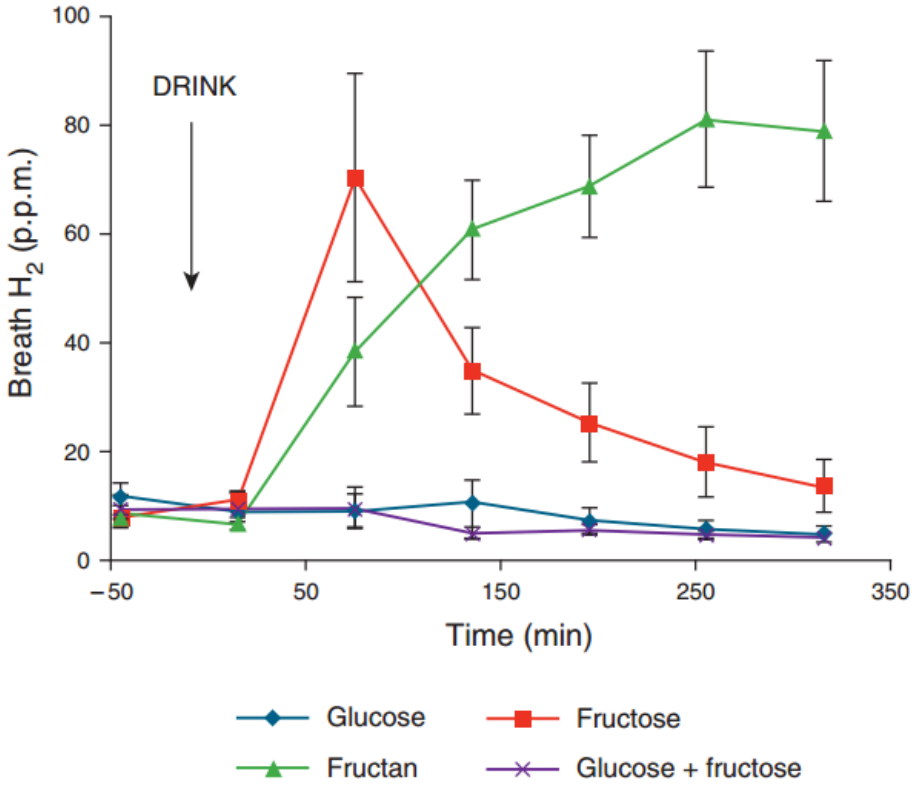
- Lactose. Lactose is only effectively digested if somebody produces enough lactase, the enzyme that breaks it down. However, lactase deficiency is widespread in the world; it effects 2% of the population in Scandinavia, about 10% in the northwestern part of Europe and over 90% in some Asian countries. (See the dairy section for more details.)
- Fructose. About 30% of the population has a very limited ability to absorb free fructose, leading to 'fructose malabsorption'. Everybody's absorptive capacity for fructose is limited to a certain extent. It's mainly absorbed through carrier-mediated diffusion, where the capacity is quite variable between individuals. On the other hand, glucose absorption is complete because it is an active transport that is facilitated by GLUT-2. If fructose is ingested as sucrose (which contains 50% fructose and 50% glucose), or in combination with a higher concentration of glucose, it is absorbed more fully (since some fructose can be absorbed with GLUT-2). However, if more than 50% comes from fructose, the absorption is lower due to lower capacity GLUT-5 transporter.
- Polyols, also known as sugar alcohols. These consists of sorbitol, xylitol, mannitol and maltitol. They are poorly absorbed in the small intestine and are readily fermented in the large intestine. At least 70% of polyols are not absorbed in healthy individuals.

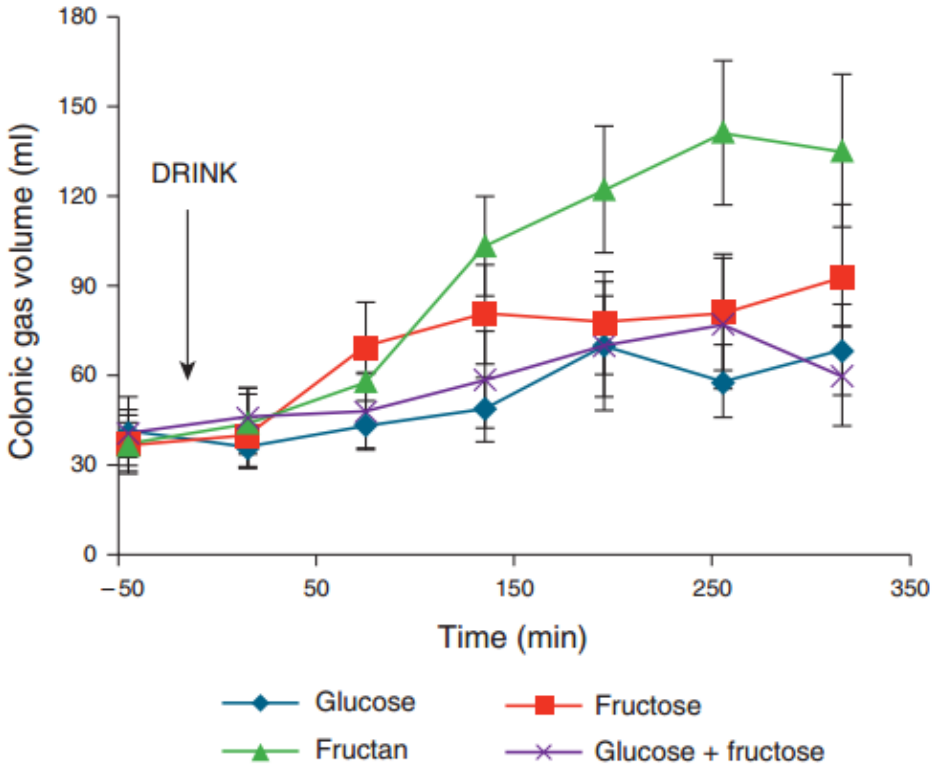


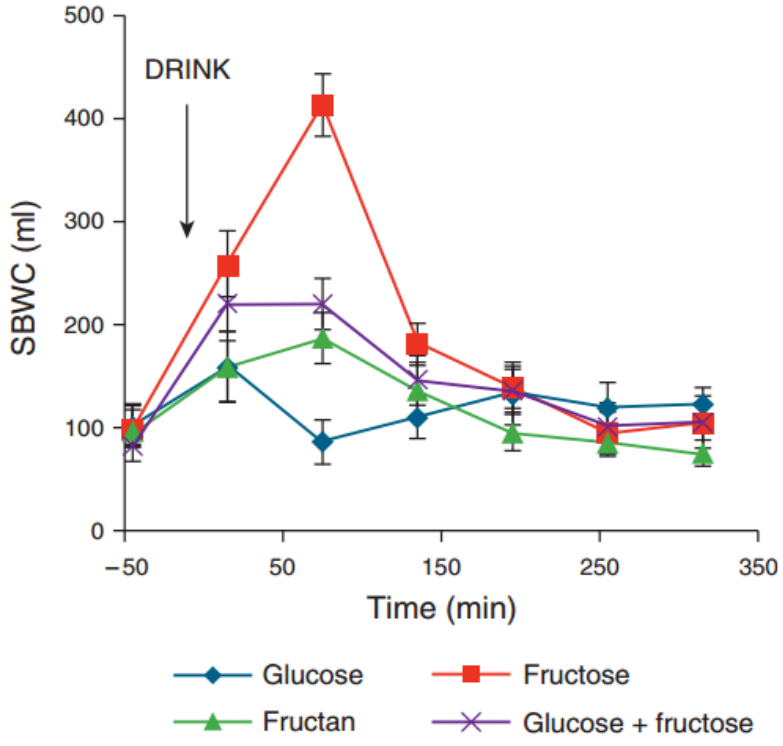
How FODMAPs can cause gut problems. Source

Excessive intake of FODMAPs can be problematic as they are poorly absorbed in the small intestine and highly fermentable in the large intestine. In susceptible individuals, this can cause flatulence, abdominal pain and bloating. In highly genetically susceptible individuals, FODMAPs may exacerbate the development of Crohn's disease. Furthermore, these unabsorbed nutrients exert osmotic forces and drag water along with them, which can lead to accelerated transit time and possibly even diarrhea. High concentration of non-absorbable nutrients in the small intestine can also lead to bacterial overgrowth, which is a common trait within irritable bowel syndrome (IBS), coeliac disease and Crohn's disease. People with IBS have also been found to have an unbalanced gut microbiota [2].

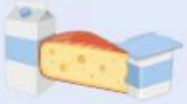
A study from 2014 tested 16 healthy individuals with no history of gastrointestinal disorders to see how various nutrients caused digestive reactions. The study was a four-way randomized single-blind crossover: on 4 different occasions, the subjects consumed 4 drinks that contained glucose, fructose, fructans or a mixed solution of both glucose and fructose in a fasted state. MRI scans of the abdomen was performed before ingestion and hourly for 5 h after the ingestion of the drink to detect water content. Breath hydrogen was also measured in all participants as a maker of fermentation in the large intestine. Fructose showed the highest increase in small bowel water content, since fructose is both osmotically active (i.e. it attracts a lot of water) and poorly absorbed. Fructan (inulin) is relatively unabsorbable in the small intestine and resulted in the highest increase in hydrogen production. Inulin and fructose also produced significantly more gas than glucose and the mixture of glucose and fructose. See the figures below for more details if you're interested.




Colonic gas volume (ml)
180
150
120
90
60
30
0
DRINK
−50
50
150
250
350
Time (min)
Glucose
Fructose
Fructan
Glucose + fructose


SBWC (ml)
500
400
300
200
100
0
DRINK
−50
50
150
250
350
Time (min)
Glucose
Fructose
Fructan
Glucose + fructose

This short video goes into more detail about FODMAPs.

	High FODMAP foods	Low FODMAP alternatives
Vegetables 	Artichoke, asparagus, cauliflower, garlic, green peas, mushrooms, onion	Carrot, cucumber, lettuce, potato, eggplant, celery, green beans, pumpkin, squash
Fruits 	Apples, apple juice, cherries, dried fruit, mango, nectarines, peaches, pears, plums, watermelon	Cantaloupe, kiwifruit, mandarin, orange, pineapple, blueberry
Dairy & alternatives 	Cow's milk, custard, ice cream, sweetened condensed milk, yoghurt, cottage cheese, ricotta cheese, soy milk (made from soybeans)	Almond milk, brie/camembert cheese, feta cheese, hard cheeses, lactose-free milk, kefir, soy milk (made from soy protein)
Protein sources 	Most legumes/pulses, some marinated meats/poultry/ seafood, some processed meats	Eggs, firm tofu, plain cooked meats/poultry/seafood, tempeh
Breads & cereals 	Wheat/rye/barley based breads, breakfast cereals, biscuits and snack products	Oatmeal. quinoa, rice, sourdough spelt bread, gluten-free products, polenta
Sugars, sweeteners 	High fructose corn syrup, honey, artifical sweeteners with sugar alcohols	Dark chocolate, maple syrup, rice malt syrup, table sugar
Nuts & seeds 	Cashews, pistachios	Macadamias, peanuts, pumpkin seeds/pepitas, walnuts

Source

Which foods contain FODMAPs

Monash University, the leading research institute on FODMAP research, also has an app for both Android and iPhone, which comes highly recommended by other researchers.

However, there is high variability in the research on which foods are high in FODMAPs and which aren't. For one, there are no official cut-off levels to determine whether a food is 'high' in FODMAPs [2], in part because it's mainly the *total* FODMAP content in a meal and the individual threshold for those FODMAP that determine whether symptoms will occur or not.

We rarely eat foods in isolation. A recent review proposes that less than 0.5g FODMAPs per sitting or less than 3 g FODMAPs per day should be consumed, but these numbers should be greatly individualized. To put these numbers in perspective, the mean FODMAP content of an Australian mixed diet is 23.7 g per day.

One recent review summarized critique of the FODMAP diet as follows:

- The quality of the FODMAPs studies are low, particularly because of a lack of a proper control group and/or blinding.
- The duration of the studies is short.
- The lists of foods are extremely long
- Drastic reduction of FODMAPs may have consequences for the intestinal microbiota, nutrition status (micronutrients and antioxidants) and colonocyte metabolism (short chain fatty acids like butyric acid).

Still, studies consistently show IBS symptoms improve when reducing FODMAPs. Here's another list of which foods are high in FODMAPs and which ones.

Table 1 Food sources of FODMAPs (where FODMAPs are problematic based on standard serving size) and suitable alternatives

FODMAP	Excess fructose	Lactose	Oligosaccharides (fructans and/or galactans)	Polyols
Problem high FODMAP food source	*Fruits:* apples, pears, nashi pears, clingstone peaches, mango, sugar snap peas, watermelon, tinned fruit in natural juice *Honey* *Sweeteners:* fructose, high fructose corn syrup *Large total fructose dose:* concentrated fruit sources; large serves of fruit, dried fruit, fruit juice	*Milk:* cow, goat and sheep (regular & low-fat), Ice cream *Yoghurt* (regular & low-fat) *Cheeses:* soft & fresh (e.g. ricotta, cottage)	*Vegetables:* artichokes, asparagus, beetroot, Brussels sprout, broccoli, cabbage, fennel, garlic, leeks, okra, onions, peas, shallots. *Cereals:* wheat & rye when eaten in large amounts (e.g. bread, pasta, couscous, crackers, biscuits) *Legumes*: chickpeas, lentils, red kidney beans, baked beans *Fruits:* watermelon, custard apple, white peaches, rambutan, persimmon	*Fruits:* apples, apricots, cherries, longon, lychee, nashi pears, nectarine, pears, peaches, plums, prunes, watermelon *Vegetables:* avocado, cauliflower, mushrooms, snow peas *Sweeteners:* sorbitol(420), mannitol(421), xylitol(967), maltitol (965), isomalt (953) & others ending in '-ol'
Suitable alternative low-FODMAP food source	*Fruit:* banana, blueberry, carambola, durian, grapefruit, grape, honeydew melon, kiwifruit, lemon, lime, mandarin, orange, passionfruit, paw paw, raspberry, rockmelon, strawberry, tangelo. *Honey substitutes:* maple syrup, golden syrup *Sweeteners:* any except polyols	*Milk:* lactose-free, rice milk *Cheese:* 'hard' cheeses including brie, camembert *Yoghurt:* lactose-free *Ice cream substitutes:* gelati, sorbet *Butter*	*Vegetables:* bamboo shoots, bok choy, carrot, celery, capsicum, choko, choy sum, corn, eggplant, green beans, lettuce, chives, parsnip, pumpkin, silverbeet, spring onion (green only), tomato *Onion/garlic substitutes:* garlic-infused oil *Cereals:* gluten-free & spelt bread/cereal products	*Fruits:* banana, blueberry, carambola, durian, grapefruit, grape, honeydew melon, kiwifruit, lemon, lime, mandarin, orange, passionfruit, paw paw, raspberry, rockmelon *Sweeteners:* sugar (sucrose), glucose, other artificial sweeteners not ending in 'ol'

Source

And another one.

	High FODMAPs
Fructans	Wheat including bread, pasta, couscous etc., onions, shallots, scallions, garlic, barley, Brussels sprouts, cabbage, broccoli, pistachio, artichoke, inulin or chickory root
Galactans	Soy milk, soy protein isolate, miso, veggie-burgers, dried beans and peas, lentils, butter/lima beans, humus, large amount (more than 1 cup per day) of coffee
Lactose	Soft cheeses including ricotta, cottage and cream cheese, milk, cream, yoghurt, butter, ice-cream
Polyols	Artificial sweeteners (xylitol, sorbitol etc.), apples, plums, cherries, pear, cauliflower, sweet corn, snow peas, mushrooms

	Low FODMAPs
Fruits	Oranges, unsweetened cranberries, strawberries, cantaloupe, lemon, lime
Vegetables	Peas, celery, carrots, plum tomato, spinach, lettuce, green peppers, green beans, bean sprouts, turnip, turnip green, cucumber
Dairy	Hard cheeses including cheddar, Swiss and parmesan. Lactose-free unsweetened yoghurt, lactose-free milk
Meats	All plain unprocessed meats, peanut butter (not sweetened with high fructose corn syrup), eggs, small amounts of almonds and walnuts, tofu
Grains	Rice (all varieties), gluten and rye-free bread, oats, corn, oat rice, buckwheat or quinoa cereals, corn tortilla, grits, popcorn, potato, quinoa

Source

Another very comprehensive but less strict list can be found here.

Practical application

There are two main strategies to utilize when applying a low FODMAP diet: the top-down or the bottom-up approach.

- The top-down approach starts with an elimination diet, removing all high-FODMAP foods from the diet. Then you experiment with 'oral food challenges', basically just eating a lot of a specific high-FODMAP food and seeing if you get any digestive symptoms, to see which foods you can reintroduce in your diet.
- The bottom-up approach only eliminates high-FODMAP foods one by one in order of the most likely culprit.

Table 1 Top-down and bottom-up approach to implement a low FODMAP diet

	Top-down	Bottom-up
Description	Over restriction of all or most FODMAPs to the cut-off levels set by Monash University, then liberalization of diet to tolerance level	Reduction of foods with very large amount or specific FODMAPs, then continued restriction to tolerance level
Usual duration	4–8 weeks	4–8 weeks
Suitable IBS population	• Patients in whom the success of the low FODMAP diet or type/amount of FODMAP tolerance is uncertain • Patients who do not normally eat a lot of FODMAPs • Patients who are very symptomatic • Patients who prefer this approach	• Patients who eat a lot of FODMAPs • Patients who are mildly symptomatic • Patients in whom prebiotics are particularly important • Patients who prefer this approach
Possible contraindications	• Patients who are nutritionally compromised • Patients with eating disorders • Children • Patients with other dietary restrictions	–

Foods should gradually be phased back in while symptoms are monitored. This approach minimizes unnecessary dietary restrictions, ensures that the diet contains enough variability and also makes it simpler to consume all micronutrients.

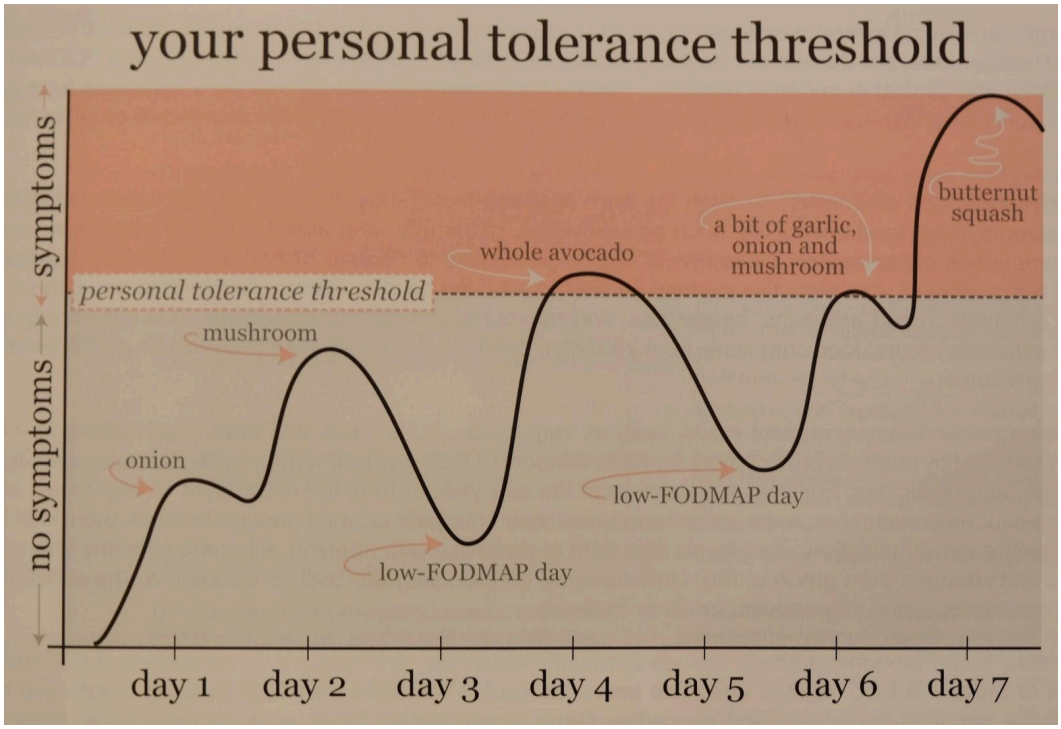
The top-down approach is the most frequently used and successful method of implementation, because it is much easier to establish whether FODMAPs are indeed the issue and then to see which foods you are intolerant to.

The start consists of two different phases: the **elimination diet** and the **reintroduction challenge**. The Monash researchers recommend that a full low-FODMAP diet is followed for 2-6 weeks during this elimination diet, while others suggest a full 8 weeks. It is important to follow a strict low FODMAP diet in this phase so that all or most of the symptoms will improve or completely subside. A food diary with symptoms is advisable. Occasional intake of higher FODMAPs in this phase may not induce symptoms, since the overall load of FODMAPs are reduced. However, one must make sure to go back to the elimination diet so that they can figure out which sources they are more tolerant to. After the elimination phase, you start to re-introduce higher FODMAPs.

FODMAP testing has to be done gradually. If you test all foods at once, you'll have no idea which ones you tolerate better or worse. Say that you start to test out disaccharides, which includes lactose. Look up which food sources that contain lactose, try them in small amounts and register if any symptoms occur. Find your limit and go on to the next FODMAP type a day or two later.

It is likely at some stage that your symptoms will reappear when you find trigger foods. These symptoms could last for a few days. When this happens, note it down in your diary, go back to the low FODMAP elimination diet (plus the foods that you have re-introduced with no symptoms) and try another type of FODMAPs a few days later. You can also opt to try the same type of FODMAP, just in a smaller amount. For more details about the reintroduction phase, you can read this article.

It's important to note that there's no 'one-size-fits-all' application to this diet, as people's response to FODMAPs are highly individual.



Source

FODMAP intolerance testing is very much a process of trial and error, but it should be a *systematic* one. You may wonder if there aren't any simpler, quicker methods to detect which FODMAPs you're intolerant to. There aren't. Though many organizations claim to have one based on bloodwork, breath, urine or fecal testing, current anti-body testing cannot identify which foods you're intolerant to [2], mainly due to a large amount of false positives. These tests are bunk and will give a wide array of false positives as well as negatives.

Sponsorship bias in health sciences

Health science studies are often industry funded, because many scientific research studies require much more funding than individuals and often even universities can cough up for the public good. Even relatively small exercise science studies can cost tens of thousands of dollars. Large-scale health science studies with many laboratory measurements are simply unaffordable for many researchers without external funding. Only organizations with a lot of money and a vested interest in the study are likely to spend that much money on a study and that means we rely on the big companies in the private sector. For example, a lot of dairy research is funded by the dairy industry.

A financial conflict of interest from a study's sponsors begs the question if the study was impartially conducted or if the research was biased. We can answer this question scientifically by comparing studies of funded vs. independent research on a topic to determine if they report different results. Several reviews and meta-analyses have done this and found there are no significant differences between the results of industry-funded and independently funded studies on the health effects of food groups [2, 3, 4]. So just because a study has a financial conflict of interest does not mean we should dismiss its results. In fact, dismissing a study purely based on its funding is itself a clear bias.

Industry sponsorship does influence the health science research agenda [2], meaning corporations have a big say in what gets studied in the first place. This is to be expected of course. Corporations will selectively fund research that they expect will cast their products in a favorable light. For example, the dairy industry will be more likely to fund research on the health benefits of calcium than research on how to promote vegan diet acceptance. Nevertheless, the research that gets conducted on food groups tends to be impartial. Often, corporations give money to a university or

research group to conduct the study, but the researchers conducting the actual study do not have a financial conflict of interest.

That said, the financial sponsorship bias increases significantly when we look at research on specific food products, especially branded products like Coca-Cola. Research on fruit juices, sodas and milk appears to be majorly biased [2], and there is also significant bias present in research on artificial sweeteners, interestingly both from proponents reporting improbably many favorable results as well as from industry competitors reporting improbably many adverse results.

The bad reputation of sponsored research is mostly due to the pharmaceutical industry. 'Big pharma' is notorious for influencing scientific studies on its drugs. Studies funded by the pharmaceutical industry tend to report more favorable findings than independent research studies [2, 3, 4]. There is little evidence of outright data fraud though and some research didn't even find evidence of sponsorship bias. Usually, the bias is evident only in which results are emphasized, how the data are analyzed and what the researchers conclude and recommend, not in the raw data. Health care interventions also don't seem to suffer from much reporting bias, but they do suffer from publication bias: what's reported appears to be genuine, but unfavorable results from industry funded research are less likely to be published in the first place.

In the end, you should always be extra skeptical of research from financially biased parties, but you can probably trust most published data on the health effects of food groups. The key is to critically examine the study data and draw your own conclusions. Don't blindly trust in the conclusions of the researchers if they are potentially biased, but don't dismiss the study altogether a priori either.

Summary: food choices for optimal health

The following hierarchy provides an overview of recommended food choices for optimal health. Note that this is not all there is to food, as this hierarchy does not consider the food's anabolic effects or satiety index.

Tier 1 'Very healthy diet staples'

- Non-starchy vegetables
- Seafood
- Berries
- Avocado
- Olives
- Nuts, seeds and legumes
- Herbs & spices, gelatin, decaf coffee, decaf tea, herbal tea, vinegar

Tier 2 'Healthy additions'

- Whole fruits
- Poultry (notably incl. liver and kidney, but only up to 3x per week in men to avoid potential iron toxicity)
- Unpasteurized/raw kefir, yogurts and quark
- Tubers/root vegetables/potatoes
- Whole cereal grains (preferably traditionally prepared, e.g. fermented)
- Dark chocolate (> 80% cacao)
- Home-made bone broth

Tier 3 'Pros and cons: healthy in a balanced diet'

- Non-fermented/pasteurized dairy and cheeses (e.g. whole milk, cottage cheese, cheeses, grass-fed butter)

- Unprocessed red meats
- Alcohol-free red wine
- Coconut products
- Eggs (preferably omega-3 eggs)
- Soy products, ideally fermented

Tier 4 'Neutral'

- Artificial sweeteners (all kinds)
- Zero calorie sodas
- PUFA-rich vegetable oils without any trans fats

Tier 5 'Risky: limit consumption'

- Sugars & syrups (all kinds)
- White/milk chocolate
- Refined grains
- Processed red meats

Tier 6 'Harmful: best to completely avoid'

- Anything with partially hydrogenated or hardened vegetable fats and artificial trans fats
- Alcohol
- Tobacco products

Illness

Getting sick sucks. Fortunately, if you live a healthy lifestyle, you should rarely ever get sick. In case you do, the tips from the following article will help you get well as quickly as possible.

➢ Guide

11 Tips to bolster your immune system against illness