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THE KETOGENIC DIET

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Contents

➢ Lecture [optional]

The ketogenic diet for strength trainees

Correction: at 36m29s the lecture says 75% resynthesis, but it should say 'resynthesis back to 75% of baseline'. Either way, this rate should result in complete resynthesis in 24 h.

The ketogenic diet is one of those topics surrounded by mystery and a large emotional baggage. Some people love it, while others hate it, with seemingly very little middle ground. Let's look at what the science says about the utility of ketogenic diets for strength trainees.

What is a ketogenic diet?

Certain tissues like the central nervous system, notably the brain, cannot use fat as fuel, because fatty acids cannot cross the blood-brain barrier. When glucose is scarce in the diet as a result of a low carbohydrate intake, the liver converts fatty acids to ketones, which the brain can use. Most tissues that can burn glucose can also burn ketones, including the brain and muscle. Interestingly, the liver doesn't burn ketones, though it produces them. The brain also cannot exclusively run on ketones and seems to require a small proportion of glucose for energy production.

Specifically, during ketogenesis the liver converts acetyl-CoA to 3 ketone bodies.

1. Acetoacetate, which isn't very prevalent.
2. β-hydroxybutyric acid (bHB), the primary ketone though it's technically not a ketone.
3. Acetone, which doesn't really do much except give you the distinct 'keto breath' when it is expelled via the lungs, causing a somewhat sweet and fruity odor that some people smell during a ketogenic diet.

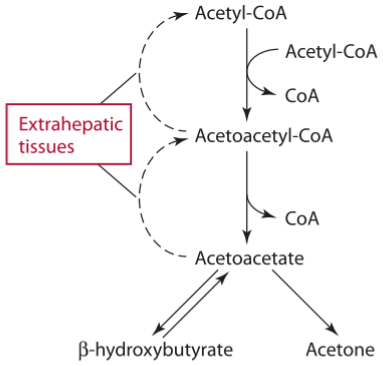


Figure 5.27 Steps in ketone body formation.

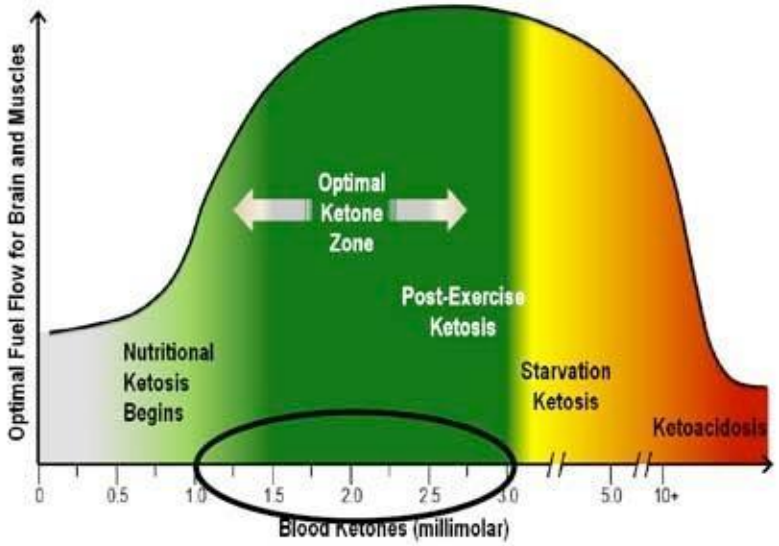
Fatty acids cannot be freely transported in the blood stream because of their hydrophobic properties, but ketones are water soluble. Acetoacetate and β-hydroxybutyrate can therefore be transported by the blood to peripheral tissues, where they can be converted back to acetyl-CoA and oxidized through the TCA cycle. The transport of fatty acids in the blood stream is carried out by VLDL and chylomicron.

In addition to their advantage over fatty acids in ease of transport, ketones can replace glucose as fuel in most of the body. Certain tissues, such as heart muscle and the renal cortex, even preferentially use ketones to glucose.

Ketosis is often associated with starvation. In our evolutionary past, fasting was probably the main scenario in which we would enter ketosis. However, ketosis is not a disease or pathology. It's a functional, adaptative state. Ketones are a normal part of human energy production. In fact, ketones are almost always present in the blood to some degree and ketosis exists on a continuum. Ketone bodies can be produced during intense exercise and fasting, including the overnight fast when we sleep. When ketone levels increase to 0.5 millimolar (mM), they become a preferred fuel source for the brain and at this point we generally say someone is 'in ketosis'. So strictly speaking, almost everyone, especially any person practicing intermittent fasting, is on a cyclical ketogenic diet.

The misconception that you're either in ketosis or you're not is based partly on a wrong interpretation of the 'ketosis sweet spot' proposed by Volek & Phinney. As you can see below, Volek & Phinney are actually very clear about the nature of ketosis as a continuum. They just make the dubious claim that there is an optimal level of ketosis, but there's no research to support this. There is no direct correlation between someone's level of ketosis and their rate of fat loss [2]. Harvey et al. (2019) also found

no significant differences in mood and wellbeing of ketogenic diets with 5%, 15% or 25% carbohydrate intake, despite significant differences in the degree of ketosis. However, there was a trend for the 5% carbohydrate group to experience more severe carbohydrate withdrawal symptoms and greater difficulty with dietary adherence, suggesting excess carbohydrate restriction may be undesirable for most people.



Page 91: The Art and Science of Low Carbohydrate Performance
Jeff S. Volek and Stephen D. Phinney

How do I go into ketosis?

It generally takes at least 48 hours of low carb dieting to reach what is defined as 'nutritional ketosis'. The exact timeframe depends on the amount of physical activity performed, the degree of carbohydrate restriction, the levels of various hormones, notably insulin and various genetic factors.

The required degree of carbohydrate restriction for long term ketosis is between 20-50 grams of net carbs a day for the majority of people, though exceptions have been found of people that can consume up to 192 grams of carbs with elevated ketone production. We've compiled a research overview here of studies measuring the level of ketosis in relation to a given macronutrient composition. There is never a need to remove carbohydrates from the diet entirely. In fact, you should rather think of trying to consume as many carbs as you can during a ketogenic diet while still reaching your desired level of ketosis. There's no possible justification to completely remove a whole macronutrient and all the foods it is present in, including what is arguably the most nutritious class of foods on the planet, vegetables.

Moreover, it is crucial to realize that glucose levels, not actual carbohydrate intake, determine the onset of ketone production.

That's why you only have to count *net* carbs, which are equal to your total carb intake minus your fiber intake. A diet with 40 grams of fiber and 90 grams of carbohydrate thus only has 50 grams of net carbs, quite possibly low enough to be a mildly ketogenic diet.

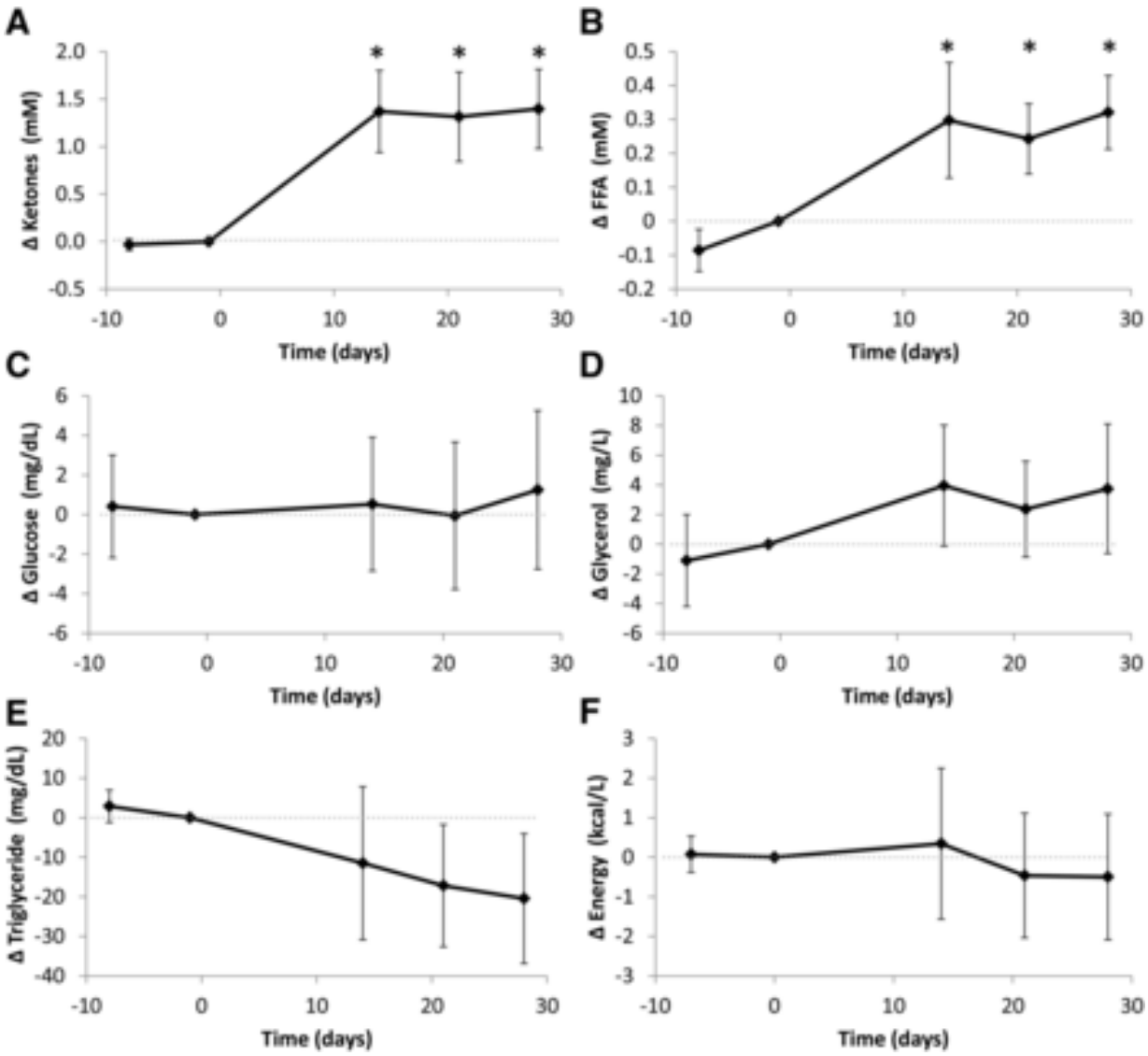
Since most amino acids can be converted to glucose, you also have to consider protein intake. This is sometimes taken to extremes with the result of prescribing low protein intakes for all ketogenic diets. That's a major mistake, as a sufficient protein

intake is far more important for most intents and purposes of strength trainees than the level of dietary ketosis. A ketogenic diet does not require suboptimal protein intakes. Multiple studies have shown that you can be in ketosis on optimal protein intakes, sometimes even on protein intakes as high as 2.7 g/kg (1.2 g/lb) per day.

On average, only 57 grams of glucose can be created from 100 grams of protein. As a guideline, you can count half of your excess protein intake towards your net carb intake. See the course module on protein for what constitutes the excess: anything above 1.8 g/kg (0.82 g/lb) per day is a good guideline. If you're monitoring your level of ketosis (detailed later on), you can test for yourself relatively easily if a higher protein intake will drive you out of ketosis.

Keto-adaptations

When you go into ketosis, your metabolism adapts in various ways to the switch in substrate use from glucose to ketones. We can measure the keto-adaptation process with various biomarkers, as illustrated below. Keto-adaptation is commonly claimed to last months, but most metabolic keto-adaptations require only 2 weeks. Many people presumably mistake their coping with ketosis and low-carbohydrate food choices with metabolic adaptations.



Metabolic changes during keto-adaptation. Source

The ‘keto flu’

During the first 2-5 days of a ketogenic diet, some people experience the ‘keto flu’ with severe lethargy. Many people give up at this point and conclude that keto diets don’t work them and proceed to make a dozen posts on Instagram about the evils of keto diets.

The keto flu seems to result primarily from low electrolyte levels. Many people majorly decrease their consumption of plants on ketogenic diet, resulting in a low intake of potassium, magnesium and sodium if total salted food volume decreases. A ketogenic diet is not an excuse to live on nothing but eggs, butter and bacon. That’s just as bad for your health as in a non-ketogenic diet. In fact, in terms of minerals, it’s even worse, because transitioning to a low-carbohydrate diets increases sodium and potassium excretion for ~2 weeks. Insulin has an anti-natriuretic effect: it prevents the kidneys from excreting sodium. So high insulin levels increase sodium retention. This is part of the reason chronically elevated insulin levels can increase blood pressure.

You should therefore increase your intake of sodium and potassium on low-carbohydrate diets. Anecdotally, increasing sodium, potassium and magnesium consumption often alleviates the keto flu fatigue. The increase in sodium excretion only amounts to a few hundred milligrams for most individuals and it’s a temporary increase, so a royal intake of salted vegetables and liberal use of table salt (preferably iodized, as we’ll discuss in the micronutrition module) should suffice for potassium and sodium. For magnesium, supplementation of 200-400 mg magnesium citrate may be advisable, as we’ll discuss further in the micronutrition module. However, individuals that don’t naturally eat a lot of salt or who experience persist fatigue in ketosis should experiment with supplementing up to a few grams of table salt pre-workout to see if makes them feel better.

To emphasize again, you should also take care during a ketogenic diet to still cover all your micronutrient requirements. Careless implementation of low carb diets can result in micronutrient deficiencies.

A potential other way to shorten the keto flu period and reduce its severity is to consume medium-chain triglyceride (MCT) oil. A study by Harvey et al. (2018) found a trend for MCT oil to speed up the achievement of initial ketosis and reduce the symptoms of the keto flu compared to sunflower oil, but most comparisons did not reach statistical significance and several participants experience digestive side-effects, such as abdominal pain. As such, it may be worth trying some recipes with coconut oil during the keto flu period to get it over with as soon as possible, but spending money and calories on MCT oil may not be worth it unless your keto flu is particularly bad. We'll discuss MCT oil in more detail in its own section further on in this module.

Water retention

The increased sodium excretion in ketosis has a significant effect on your bodyweight. It's not uncommon to lose 1-2 kg of weight within the first week of a ketogenic diet, sometimes more in large energy deficits. While some of this is the expected fat loss from cutting, much of it is water. Water follows sodium in the body due to osmosis, so ketogenic diets cause considerable water losses from the body. Since ketogenic diets chronically reduce insulin levels, you don't gain the water back until you increase your carbohydrate intake. You should take this water loss into account when interpreting your weekly body composition data. Large weight loss after transitioning into ketosis does not necessarily mean your energy deficit is excessive, nor does it mean that the diet is magically effective for fat loss.

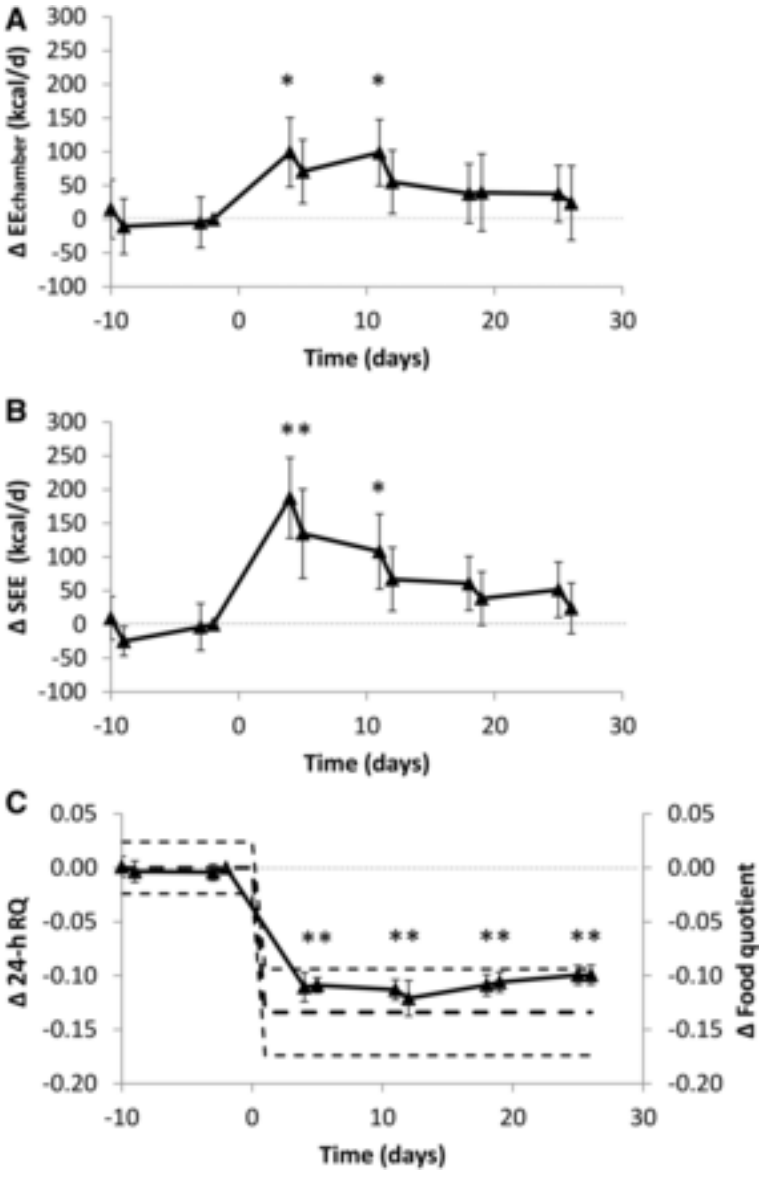
Other than the drop in scale weight, you'll probably also notice that you literally look drier and leaner in ketosis due to the reduction in subcutaneous water storage. However, since you also lose intramuscular water and glycogen, you also look flatter and it may be more difficult to get a pump in the gym. This is the inherent trade-off between higher and lower carbohydrate diets: low-carb diets make you look leaner, yet high-carb diets make you look bigger. This visual effect resulting from changes in water and glycogen storage is probably a big part of the misconception that keto diets are remarkably effective for fat loss but ineffective for muscle growth. We'll go into more detail on body composition changes later.

Energy expenditure

The conversion of thyroid hormones T4 to T3 is moderately inhibited during low carb diets. Theoretically you may expect this to be accompanied with a lower metabolic rate, but your body is capable of regulating thyroid hormone activity very well. Your body adapts and energy expenditure and RMR remain the same regardless of the amount of carbohydrates in your diet [2, 3, 4]. If anything, it seems lower-carb diets increase total daily energy expenditure slightly, as you learned in the course module on carbohydrates.

Energy expenditure may even slightly increase during keto-adaptation due to increased protein utilization and nitrogen losses, presumably resulting from protein oxidation and conversion of protein to glucose when the body is not yet relying on ketones. Without an energy deficit, nitrogen balance in ketosis stabilizes within a week and other research finds the change in amino acid metabolism during keto adaptation does not affect total body protein losses, so there is probably no concern for muscle loss. Regardless, it's important to maintain a high protein intake during keto-adaptation.

Since ketosis does not inherently affect energy expenditure, it logically follows from the laws of thermodynamics that given the same energy intake, ketogenic diets have the same effect on your energy balance as non-ketogenic diets. Ketogenic diets are thus not superior or inferior to higher-carbohydrate diets for fat loss. In the section on muscle growth and strength development, you'll see that ketogenic diets indeed result in similar fat loss as other isocaloric and isonitrogenous diets.



Total (A) and sleeping (B) energy expenditure during the transition into ketosis, along with the respiratory quotient (C). Source

Psychological and cognitive effects

After the initial keto-adaptation period, many people report that keto diets increase mental performance and wellbeing compared to higher carb diets [2, 3], but in other research mental functioning is unaffected by the carbohydrate content of the diet [2].

Deeper ketosis does not seem to improve the psychological benefits and may in fact work adversely. Harvey et al. (2019) found no considerable differences in the subjective experience of ketogenic diets with 5%, 15% or 25% carbohydrate intake, but there was a trend for the 5% carbohydrate group to experience worse symptoms of carbohydrate withdrawal and have greater difficulty with dietary adherence.

There is major interindividual variance on how people feel in ketosis and the cognitive effect of a ketogenic diet probably depends on the exact implementation. Increased cognitive functioning in ketosis may be related to the increased production of catecholamines, a group of neurotransmitters part of the human 'fight or flight' response.

Ketogenic diets are often said to have poor sustainability. However, this reputation is largely based on poor implementations of the ketogenic diet and studies where people were randomized to a ketogenic diet group, meaning people were forced into a ketogenic diet. That's of course a very different scenario than someone deliberately and intelligently implementing a ketogenic diet with a specific goal. Even in such studies, a 2020 meta-analysis found that the adherence rate of ketogenic diets is similar to that of isocaloric non-ketogenic diets. Even the Atkins diet, the most popular ketogenic diet, has a similar adherence rate to more moderate diets. After a year there was a trend for a higher discontinuation rate in the Atkins group compared to some others, but this trend was also present for the Ornish diet, which is very low fat. The Atkins diet is a needlessly strict and unhealthy version of ketogenic dieting. Excessive

carbohydrate restriction increases dietary adherence problems. More moderate ketogenic diets in general don't seem to be more difficult to adhere to than other diets and it's mostly a matter of individual preference.

Protein balance

After keto-adaptation, ketogenic diets may be protein sparing. There is a mechanistic basis for anti-catabolic effects of ketones, but almost all research showing improved protein or nitrogen balance is in states of high inflammation or disease. One small study found that while nitrogen balance decreased in the initial weeks of ketosis, afterwards it increased to the point that nitrogen balance was higher in ketosis than outside of ketosis. The increase in nitrogen retention during ketosis was accompanied with an increase in lean body mass retention during the diet, so in the long term there may be truth to the idea that a ketogenic diet is protein sparing. We'll discuss whether this affects muscle growth later.

Appetite

A ketogenic diet's key benefit is arguably its appetite suppressing effect. The appetite suppressive effect of ketogenic diets is so strong that in many studies, people report being less hungry even after substantial weight loss on the diet and in other research, ketogenic diets result in less hunger than the same weight loss from a non-ketogenic diet and hunger levels even increase when going to a non-ketogenic maintenance diet after the weight loss phase. Normally, dieting increases your appetite as body fat levels decrease along with leptin production.

However, not everyone experiences this decrease in hunger to the same degree and some people seem to not experience it at all. We don't even know *exactly* why ketosis

is so appetite suppressing. There also doesn't seem to be a relation between the degree of ketosis and subjective appetite [2], although βHB plasma concentration in fasting is associated with lower concentrations of the hunger hormone ghrelin and increased concentrations of the satiety hormones GLP-1 and CCK in some research. Whatever the mechanism, it may need time to kick in: it can take 3 weeks before the appetite suppressing effects of a ketogenic diet occur.

The appetite suppression makes ketogenic diets attractive for ad libitum dieting (eating based on your appetite rather than planned macros), which we'll discuss later in the course. It cannot be true ad libitum dieting, however, as you typically have to monitor your net carb intake to stay in ketosis.

Health effects

For those new to the ketogenic diet, the first question is usually: is such a low carbohydrate intake safe? Yes, it is, at least when properly implemented. Ketogenic diets do not adversely affect relevant health biomarkers in most studies and are generally considered very safe. Ketogenic diets are a very established treatment for overweight individuals to lose fat and improve their health in the process.

While ketogenic diets are safe and healthy when properly implemented, they don't appear to be inherently healthier than higher-carb diets. Many studies find that ketogenic and non-ketogenic diets don't significantly differ in their effects on cardiometabolic health biomarkers [2]. A small 2023 meta-analysis found that ketogenic diets slightly raised "bad" LDL-cholesterol and ApoB levels compared to higher-carb diets, although this was partially offset by an increase in "good" HDL-cholesterol. Triglyceride levels didn't differ between groups, but other research finds a paradoxical decrease in triglycerides on high-fat diets, seemingly due to

increased triglyceride synthesis on high-carb diets. While many other studies, including in bodybuilders, find lower-carb diets result in greater health improvements than higher-carb diets, that's likely because people generally lose more fat (or at least weight) on lower-carb diets [2, 3, 4], in part because of a higher protein intake and in part because of greater ease with energy restriction (**not** because of any inherent fat loss benefit of carb restriction independent of energy balance). A 2024 meta-analysis also found that ketogenic diets result in greater reduction in inflammatory markers than control diets, but again it's unclear to what extent that was caused by ketosis per se or greater fat loss.

A case could be made that the lack of health benefits of ketosis is the result of insufficient carbohydrate restriction. Some studies [2] find carbohydrate restriction improves HDL-cholesterol and triglyceride levels independent of weight loss, with greater improvements with greater carb restriction. Since most large-scale studies in the general population suffer from terrible dietary adherence (in all study groups, not just the keto group), most people don't manage to stay in ketosis long-term and therefore may fail to obtain its health benefits.

Even in type II diabetics, multiple studies and meta-analyses find no significant differences in any health outcome between higher and lower carb diets [2], but the overall literature indicates lower carb diets are likely healthier.

- A 2018 meta-analysis by Huntriss et al. found that for type II diabetics, low carb diets resulted in greater improvements in HDL-cholesterol, triglycerides and blood sugar levels (HbA1c) than the usual care diet with more carbs.
- A 2017 meta-analysis by Snorgaard et al. also found that low carb diets were better at lowering blood glucose levels than higher carb diets in type II diabetics. Moreover, the degree of improvement was related to the degree of carbohydrate restriction: the lower the carb intake, the lower the blood sugar levels.

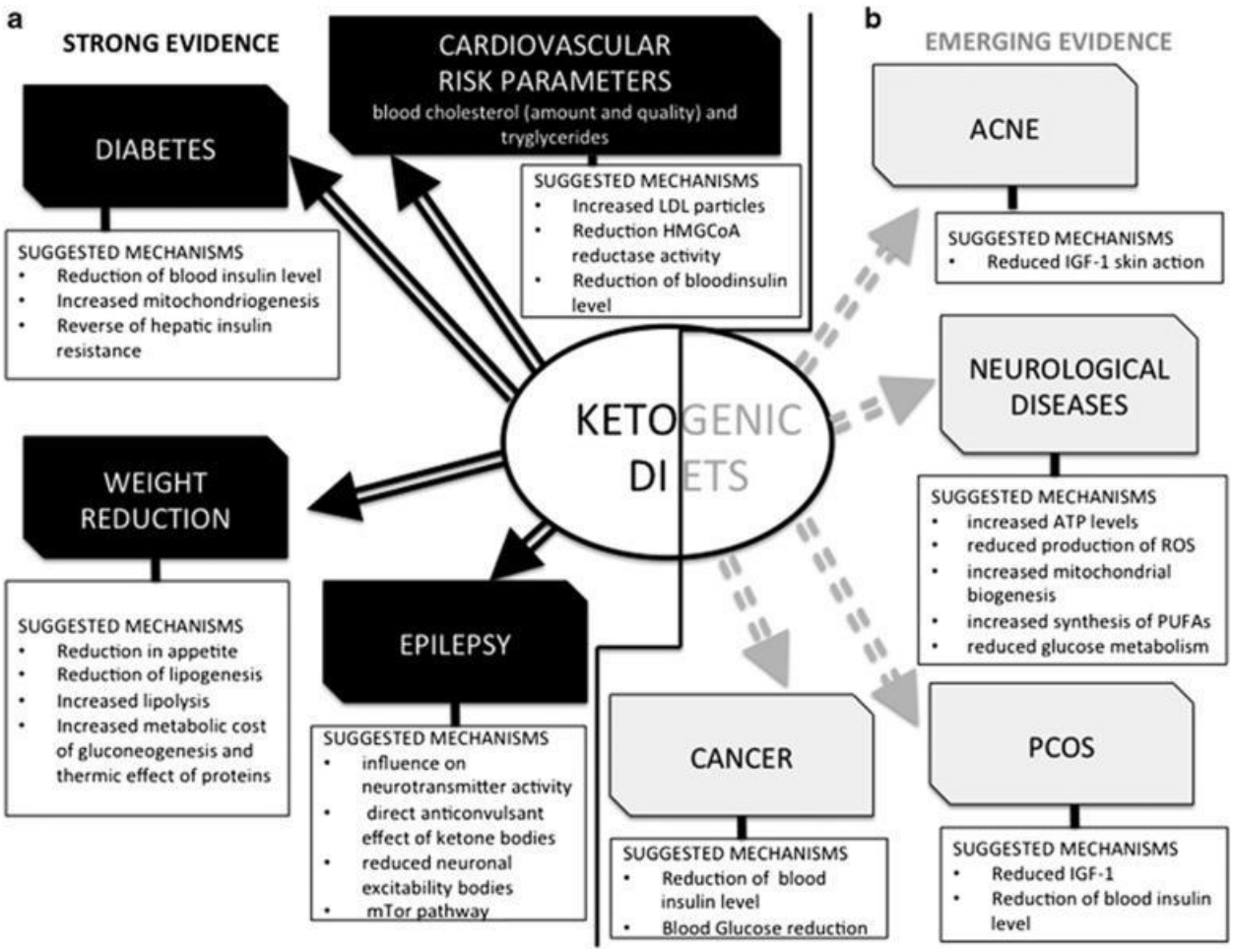
- A 2019 cohort study meta-analysis by Liu et al. further supports that the risk of developing metabolic syndrome is predicted by dietary carbohydrate intake.
- A study by Harvey et al. (2019) on ketogenic diets also found a trend for greater improvements in cardiometabolic health in individuals with worse cardiometabolic health at baseline.
- A 2022 meta-analysis of RCTs of diets for type II diabetics found that ketogenic diets reduced the reliance on medication and improved insulin sensitivity (based on A1c) compared to control diets, even after excluding studies with significant weight loss. Most health benefits for observed up to 6 months but not sustained up to 12 months, likely due to lack of long-term diet adherence.

In conclusion, ketosis per se seems to have few significant cardiometabolic health effects independent of energy restriction. Food choices are far more important than carbohydrate intake for our health. Nevertheless, low-carb diets likely offer some unique health benefits for individuals with insulin resistance. Carb intolerant individuals typically experience higher average blood sugar levels and greater blood glucose excursions on high carb intakes, so a lower carb diet can help keep blood sugar levels and thereby inflammation and cardiovascular health in check [2]. The benefits of carbohydrate restriction are not as profound as those of being lean and muscular though, so if an individual for whatever reason has a much easier time getting lean on a higher-carb diet, that's preferable over struggling with a low-carb diet.

Ketogenic diets may also offer unique health benefits specifically for the nervous system, and possibly cancer. Ketogenic diets are a well-established therapy for the control of epilepsy [2] and an accumulating body of evidence supports the overall neuroprotective effect of ketosis. Research has looked specifically at the following conditions.

- In elderly adults at risk of Alzheimer's, ketone blood levels correlate with memory performance and a ketogenic diet improved overall cognitive functioning [2, 3].
- Ketogenic diets also seem to be therapeutic during Parkinson disease [2].
- Ketogenic diets can improve migraines [2].
- Ketogenic diets may prevent severe head injury from worsening.
- There is promising but inconclusive research that ketogenic diets may reduce certain types of cancer progression [2]. Many subtypes of cancer cells preferentially rely on glycolysis as fuel and cannot use ketones, so a ketogenic diet can be used to starve these cancer cells.

The health benefits of ketosis seem to be similar to those of intermittent fasting. In fact, some of the health benefits of fasting are mediated by ketones and ketosis seems to be more protective against cancer than intermittent fasting.



Proposed health benefits of ketosis. Source

There are also many studies on overweight subjects that show unfavorable effects of ketogenic diets. The issue does not appear to be with ketosis per se here. It is with food choices. In these studies carbs are kept needlessly low, (processed) red meat intake increases, vegetable and fiber intake dramatically decrease and margarine and oils are used to provide the fat in the diet. This would be the foolish way to go about a keto diet and it generally results in an extremely unbalanced fatty acid profile with high omega-6 levels, lots of trans fat, an almost complete absence of fiber (and people wonder why they get constipated) and an insufficient intake of many essential vitamins and minerals. For example, in Rosenbaum et al. (2019), switching from a 'typical healthy Western diet' to an isocaloric and isonitrogenous ketogenic diet increased

some inflammation markers and LDL-cholesterol levels, but they failed to highlight that processed red meat intake went from zero to 2 meals a day and fiber intake decreased to less than half. Despite the overall unhealthier food choices, the overall health risk profile remained similar between the 2 diets. Saying a ketogenic diet is unhealthy based on these studies is like saying a high carb diet is unhealthy based on someone eating nothing but candy and protein powder.

A good ketogenic diet still contains large amounts of vegetables and fiber and a well-balanced fatty acid ratio. Good food choices and sufficient fiber intake are extra important on a ketogenic diet not only because carbohydrates are limited but also because a growing animal literature suggests the gut microbiota plays a significant role in ketone production.

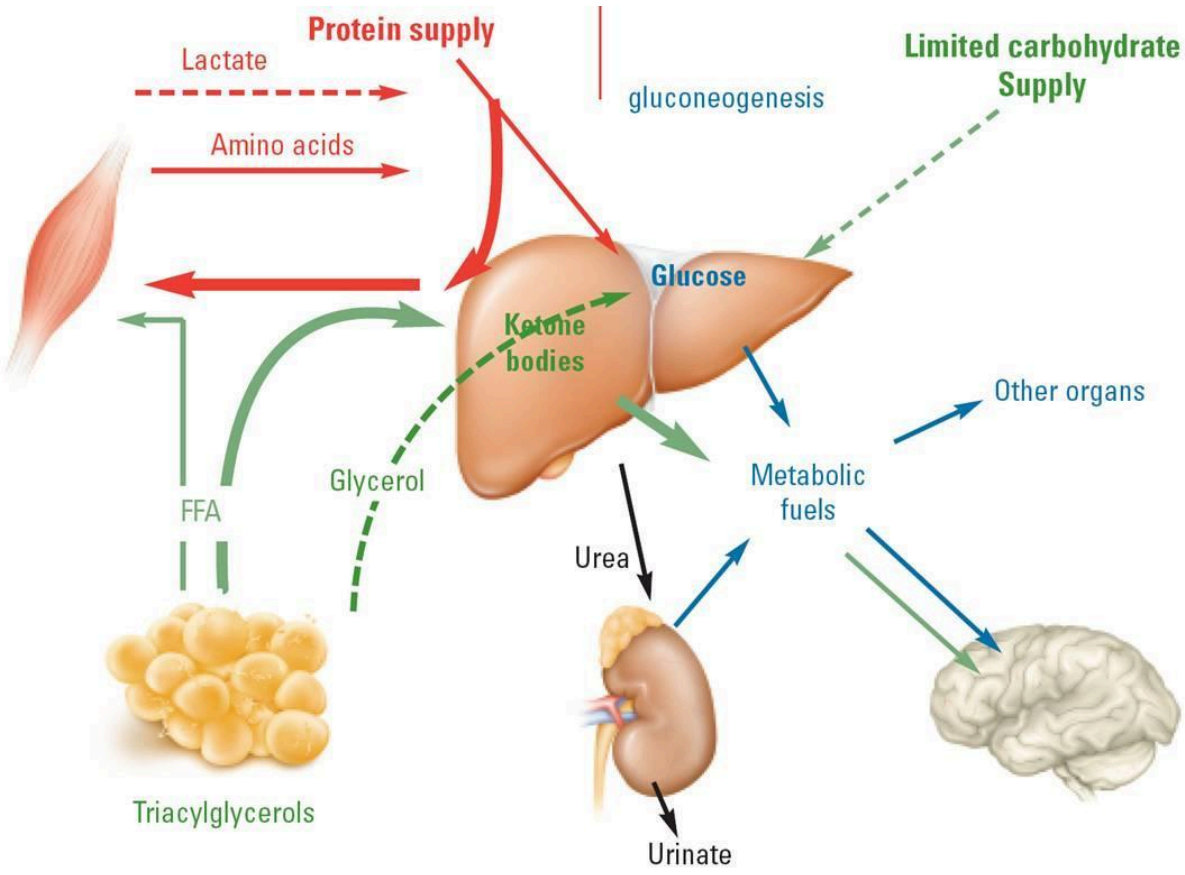
Below are some examples of good keto meals. You basically want to eat the same nutritious foods as otherwise: your selection is just more limited and skewed towards high fat sources like eggs, avocado, cheese, fattier cuts of poultry and fish.

Recipes by Sanne Leenman

All in all, ketogenic diets are normally safe and provide similar cardiometabolic health benefits as higher carb diets with a similar intake of protein, energy, fiber and micronutrients. Ketogenic diets are a gold-standard treatment for epilepsy, they're likely healthier than higher-carb diets for individuals with insulin resistance and they may offer unique health benefits for certain neurological disorders and cancer.

Exercise performance

Theoretically, you may expect a ketogenic diet to kill your performance in the gym due to the lack of carbs. However, as you've learned in the module on carbohydrates, glycogen depletion during strength training is modest, only up to 39%, and full glycogen resynthesis can occur within 24 hours even via solely carbohydrate-independent pathways (the Cori cycle and gluconeogenesis from glucogenic amino acids or the glycerol backbone of triglycerides). Thus, the body is very capable of synthesizing enough glycogen for maximum strength training performance even with a very limited carbohydrate intake.



Ways the body can create glucose. If you can't fully explain this graphic, revisit the module on carbohydrates, as this is important to understand.

A 2022 systematic review of the literature by Henselmans et al. found that carbohydrate intake does not impact exercise performance in most studies.

For example, in a 6-month cross-over trial of Olympic Weightlifters and Powerlifters, an ad libitum ketogenic diet did not affect lifting performance compared to a higher carbohydrate diet, even though the ketogenic diet resulted in significantly greater bodyweight loss (~3 kg) and lean body mass loss (~2 kg). The lost mass was likely mostly water weight, as fat mass changes, self-reported total energy intake, 1RM strength and total work capacity were unaffected by diet type, strongly suggesting no difference in muscle or fat mass.

Ketogenic dieting with only ~22 grams of carbs a day has been found to have no impact on strength performance in international level gymnasts training on average 4.3 hours a day.

Similarly, a ketogenic diet had no effect on strength performance in Taekwondo athletes training 5 hours a day, 6 days a week. “The daily plan of the program consisted of 1 h of low intensity dawn exercise; 2 h of morning exercise, mostly for physical strength improvement; and 2 h of afternoon exercise, mostly for Taekwondo skills training.” This was probably pushing the limits of non-glucose energy supply, but it’s clear that low carb dieting is not the performance killer it’s often made out to be.

Even CrossFit performance has been found to be unaffected by ketogenic dieting compared to a diet with 2.6 g/kg (1.2 g/lb) carbs.

Wilson et al. (2017) again found no detrimental effects of ketogenic dieting on strength performance compared to a higher carb diet.

Lastly, yet unpublished research from Poland confirms the findings from Tampa that a ketogenic diet in bodybuilders and powerlifters does not hinder power output, though anaerobic cycling endurance was predictably impaired. As discussed during the topic on carbohydrates, it is crucial to differentiate between strength training and other forms of physical activity when assessing the need for glycogen and dietary carbs.

However, when the intensity is low enough, ketogenic dieting again does not appear to reduce performance, as the body starts using fat instead of glycogen as the primary fuel source. Several studies have found that ketogenic dieting does not impair low intensity endurance training performance [2].

So it is specifically highly anaerobic, high volume strength-endurance training that is sometimes impaired during ketogenic dieting, such as most team sports [2]. Even if total glycogen stores are adequate, the mild acidosis caused by being in ketosis may limit the rate of anaerobic metabolism. Even then, some research finds ketogenic dieting does not impair longer-duration high-intensity interval training performance (3 min. runs with 1.5 mins. rest intervals) [2].

Below you'll find an overview of the literature on the effect of ketogenic dieting on strength training performance. As you can see, ketosis generally doesn't affect strength training performance.

Study	Key findings
Paoli et al. (2012)	No effect of ~22 g carb restriction on international level gymnasts' performance training 4.3 h per day vs. 266 g carbs Western diet baseline (note: keto increased PRO).
Rhyu & Cho (2017)	Keto with 22 g carbs and 40% carb Korean diet similarly improved performance in Taekwondo athletes training 5 h per day.
Gregory (2016; thesis)	Keto with 44 g carbs and 2.6 g/kg (1.2 g/lb) carbs diet similarly improved CrossFit performance.
Wilson et al. (2017)	No effect of keto with 30 g carbs on strength or total work vs. 55% carbs Western diet.
Zajac et al. (unpublished)	No effect of keto on peak power but Wingate work was impaired in PLs and BBs on 15% vs. 50% carbs.
Agee (2015; thesis)	No effect of keto diet on strength development in Powerlifters (Note: terrible compliance, keto far lower in kcal and PRO).
Sawyer et al. (2013)	Switching from 41% to 5% carbs maintained maximal strength, power and strength-endurance in trained men and women
Kysel et al. (2020)	No significant difference in strength development between a cyclical ketogenic diet and a protein and calorie-matched moderate World Health Organization diet.
Paoli et al. (2021)	No difference in strength development on the bench press or squat in competitive natural bodybuilders on a ketogenic vs. Western diet.

Muscle growth and strength development

How do ketogenic diets fare for muscle growth? Low-carb or rather high-fat and high-protein diets have historically been prized at many times for being good for bodybuilders, but in modern times, high-carb diets have become more popular. The traditional basis for high-carb diets was that you need them for performance and if you can't perform, you can't stimulate muscle growth effectively. However, knowing that strength training performance is generally unaffected by carbohydrate intake, independent of energy intake, there's no established mechanism by which lack of carbohydrates would impair muscle growth. A potential negative effect of the ketogenic diet on muscle growth is the low chronic insulin levels, which may also reduce IGF-1 levels. However, as you learned in the course module on carbohydrates, a high protein intake generally stimulates insulin secretion sufficiently to maximize muscle protein synthesis, making carbohydrates redundant.

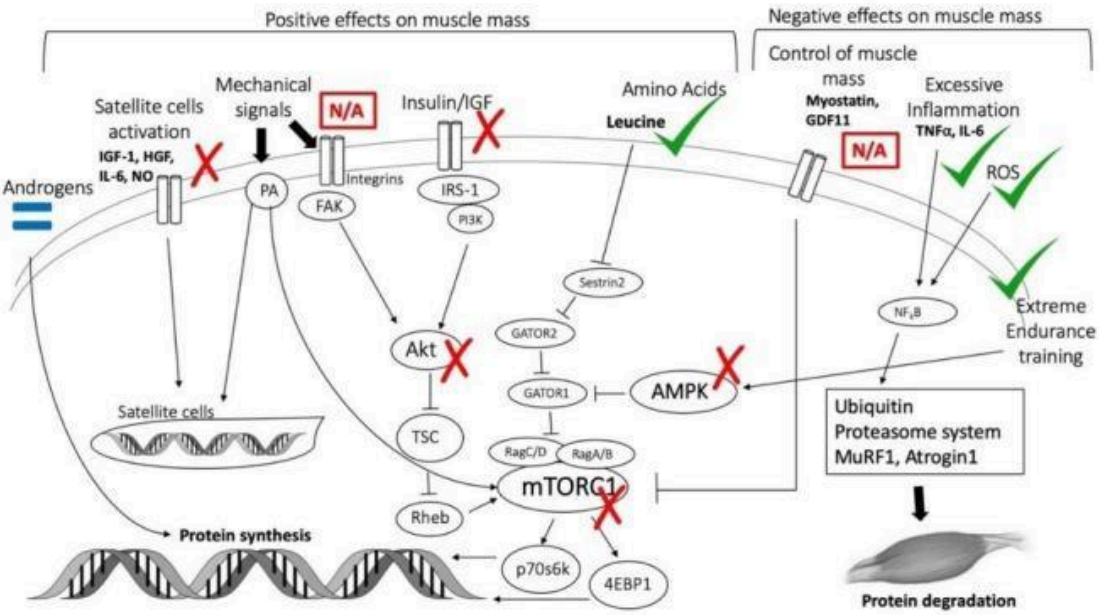
There are also no established mechanisms by which ketosis would enhance muscle growth, although there are a few theories.

1. As we've discussed in the topic on fat intake, one of the main benefits of a high fat diet is the increased anabolic hormone production. Higher testosterone levels should result in more muscle growth. However, the magnitude of the hormonal increases is so small that it could only amount to a small benefit for muscle growth over the course of multiple months. Moreover, any benefit of going over a ~40% fat intake would arguably be trivial. Vidíc et al. (2021) found that a diet with 65% fat and a ketogenic diet with 75% fat both resulted in a 33-34% increase in free testosterone levels. Thus, a ketogenic diet is probably overkill for your hormones. A moderately high fat intake likely suffices.
2. Keto diets seem to be particularly effective at reducing chronic inflammation [2], which may increase muscle growth via a clearer inflammatory signal for muscle

repair. However, for non-overweight strength trainees on a healthy diet, the reduction in inflammation would arguably be trivial, as there shouldn't be much systemic inflammation to suppress.

3. Exercise may benefit from the increased production of adrenaline and noradrenaline. Adrenaline and noradrenaline are often viewed as catabolic hormones, but they can also decrease protein breakdown. However, again we would expect any benefits to be very small. In the supplements module you'll see only powerful stimulants tend to have some anti-catabolic effects.

The following graphic summarizes the theoretical positives and negatives of a ketogenic diet on muscle mass.



How a ketogenic diet can influence muscle growth pathways.

IGF-1 = insulin-like growth factor-1; HGF = Hepatocyte growth factor; IL-6=Interleukin-6; NO = Nitric Oxide; PA = phosphatidic acid; FAK = Focal adhesion kinase; IRS-1 = Insulin receptor substrate-1; PI3K = Phosphoinositide 3-kinase; AKT = protein kinase B; TSC = Tuberous sclerosis protein; Gap activity toward Rags 1; GATOR2, Gap activity toward Rags 2; AMPK = 5' adenosine monophosphate- activated protein kinase; Rheb = Ras homolog enriched in brain; mTORC1 = mammalian/mechanistic target of rapamycin complex 1; p70s6k = S6 kinase beta- 1; 4EBP1 = 4E-binding protein 1; GDF11 = Growth differentiation factor 11; TNFα = Tumor necrosis factor α; ROS = Reactive oxygen species; NF kB = nuclear factor kappa-light-chain-enhancer of activated B cells; MuRF1 = Muscle RING-finger protein-1. Source

In line with the theory, a systematic literature review by Henselmans et al. (2022) found most studies support that a ketogenic diet has no different effects on our body composition and strength than non-ketogenic diets with the same energy and protein intake. A 2022 meta-analysis by Vargas-Molina et al. also found no significant difference in muscle hypertrophy in strength trainees between ketogenic and control diets. Another 2022 meta-analysis on ketogenic vs. non-ketogenic diets for concurrent athletes found that the diets did not differentially affect body fat percentage, lean body mass, VO_{2max} or time to complete aerobic tests. The following table summarizes relevant literature on strength trainees on ketogenic vs. non-ketogenic diets. All studies had isocaloric and isonitrogenous groups, unless otherwise noted.

Study	Population (n)	Findings	Notes
Wilson et al. (2017)	25 Trained men	Trend for greater fat loss in keto vs. 55% carb Western diet; similar increases in LBM, strength and power; after carb-up trend for greater muscle growth but no longer fat loss in keto.	Prüvit sponsored; main author critiqued for publishing incredulous data (read: potential fraud)
Gregory (2016; thesis)	27 CrossFitters	Fat loss in keto but not 2.6 g/kg (1.2 g/lb) carb group; no LBM changes; similar performance improvements.	Keto was *ad lib* non-sig. 166 kcal less
Agee (2015; thesis)	~13 Powerlifters	No significant differences between groups in body composition or Powerlifting performance (trend for better fat loss in keto	Terrible compliance, keto considerably lower in kcal and PRO (not reported if sig.)
Rhyu & Cho (2017)	20 Taekwondo athletes	Similar body composition and performance changes except faster 2 km sprint in keto vs. Korean diet	40% vs. 30% protein bias in favor of keto
Zajac et al. (unpublished)	10 Bodybuilders & Powerlifters (cross-over)	No body recomposition in either keto or non-keto group	25% vs. 20% protein bias in favor of keto

Wood et al. (2012)	32 Older men with metabolic syndrome	Similar fat loss and FFM retention in keto vs. low fat diet	Keto had non-sig. higher PRO (120 g vs. 78 g)
Meirelles & Gomes (2016)	21 Overweight but trained individuals	Similar fat loss, muscle retention and strength development in keto vs. 55% carb diet	Self-selected diet group
Kysel et al. (2020)	25 Strength-trained men	No significant difference in body recomposition between a cyclical ketogenic diet and a protein and calorie-matched moderate World Health Organization diet.	Poor statistical analysis; trend for detrimental effects of CKD
Paoli et al. (2021)	19 Competitive natural bodybuilders	The keto group lost fat, while the Western group gained lean mass. No significant differences in strength development (1RM squat and bench press) or BMR between groups.	Keto group most likely in unintentional energy deficit; body comp. measured with BIA so lower LBM was probably water.
Vidic et al. (2021)	18 Strength-trained men	No significant differences between isocaloric low carb and highly ketogenic diets on strength (1RM squat and bench press) or body composition (InBody)	

Some authors argue that ketogenic diets are inherently inferior for muscle growth. Indeed, if you lump all ketogenic diet studies together and run a meta-analysis, as Koerich et al. (2022) did, you find that ketogenic diets result in more fat loss but less muscle growth than higher-carb diets. However, the specific studies finding this are confounded by energy intake. In the studies by Vargas-Molina et al. (2020), LaFountain et al. (2019) and Paoli et al. (2021) participants that started a ketogenic diet unintentionally reduced their energy intake. As a result, even studies that intended to compare a ketogenic vs. a non-ketogenic diet with the same total protein and energy intake, often do not end up with an isocaloric and isonitrogenous comparison. The ketogenic group ends up cutting with more favorable changes in fat mass, while the non-ketogenic group ends up bulking with more favorable changes in lean body mass. These studies thus cannot tell us anything about the effects of ketosis per se. However,

from a practical point of view they do indicate it can be challenging to consume enough calories on a ketogenic diet while bulking, so a ketogenic diet may be needlessly restrictive during bulking phases.

Based on the same reasoning and some data, a weak case can be made for the (practical) superiority of ketogenic diets for cutting. While the overall literature shows similar performance and body composition changes in keto and comparable non-keto diets, Agee (2015) found a non-significant trend for greater fat loss in the keto group (3 kg vs. 0.7 kg), likely as a result of the energy intake, while achieving similar increases in lean body mass and Powerlifting performance in comparison to a group consuming a higher-carbohydrate 'conventional' diet. Similarly, Gregory (2016) found CrossFitters lost fat on a ketogenic diet with a non-significantly 166 kcal lower energy intake while achieving similar changes in lean body mass and performance in comparison to a higher-carb diet. A small isocaloric and isonitrogenous study by Young et al. (1971) found progressively greater fat loss and better lean body mass preservation on 3 low-carb diets (100 vs. 60 vs. 30 g carbs). The trend was clear for underwater weighing, body circumference measurements, skinfold thicknesses and nitrogen balance. However, the study only had 8 subjects and they didn't perform structured exercise. Wilson et al. (2017) also found a trend for improved body composition changes of a ketogenic diet compared to a 55% carb 'Western' diet in trained men. Protein and energy intake were equated between groups. During the first 10 weeks, there was a trend for greater fat loss in the keto group. The keto group had a moderate carb-up in week 11 to account for differences in glycogen storage. After this, fat loss was no longer significantly different between groups but the increase in lean body mass change and muscle thickness trended in favor of the keto group. Strength and training volume development did not differ between groups. See the infographic below for further details of the study. It should be noted that Jacob Wilson and Ryan Lowery work for Prüvit, a company that sells ketone supplements, and both authors' research

has been extensively criticized by several independent groups of researchers for missing, inconsistent and outright incredulous data, including critique from Menno. In the evidence-based fitness community, many respected authors have made allegations of outright fraud, confirmed by sources that worked with Jacob Wilson before he left Tampa University under suspect circumstances. Some of the research on endurance training ketosis also shows superior body recomposition to a non-ketogenic diet with the same number of calories. Interestingly, the ketogenic diet contained 5% less protein. The researchers attributed the superior body recomposition to the ketogenic diet's higher amount of polyunsaturated fat, as blood lipids also improved more favorably in the keto group and this group was more resistant to muscle damage. Based on these data, a tenuous case can be made for the superiority of keto diets for fat loss with muscle preservation. However, anecdotal evidence isn't that promising, so it's highly dubious if a ketogenic diet has any added benefits compared to a diet that already includes the recommended fat intakes you've learned in this course.

In conclusion, ketogenic diets seem to be equally effective as higher-carb diets for strength development and muscle growth, given equal energy and protein intake. However, in practice it can be hard to bulk on ketogenic diets. The appetite suppressive effect of the diet and the limited available food choices make it difficult for some trainees to get to their required energy surplus on a bulk. You have a strict limit on the amount of carbohydrate and protein you can consume. Up to the point where your fat intake equals your protein intake, it's not too difficult to consume enough calories, as you can consume high-fat protein sources. Many of those have roughly the same amount of protein as fat. Beyond that energy intake you have to fill in your calories with pure fat sources and that restricts you largely to oils and butters. Unless you have a very specific reason to stay in ketosis, it's generally easier to increase carbohydrate intake at that point for the bulk.

The ketogenic diet: is it right for you?

The ketogenic diet is unjustifiably demonized in fitness circles, yet it can also be said that keto does not live up to its hype. The main benefit of keto diets is arguably their appetite suppression and their main downside is their dietary restrictiveness. The decision whether to use a keto diet is thus largely a psychological and practical question for most people. While it may seem like this trivializes the keto diet, both the main cost and the main benefit are of major significance. The average person is simply incapable of following a keto diet.

If diet compliance is not an issue or hunger is the main compliance issue, a ketogenic diet is strongly worth considering. It has potent health benefits and if you respond well to it, not being hungry during a cut is a benefit that cannot be overstated. Many people also find that the benefits for cognitive functioning and emotional stability alone make it worth to stay on a keto diet.

If you do not respond well to a keto diet, even after the potential keto flu, you'll at least have learned a valuable lesson about your body. For many people, a keto diet is also an excellent way to get them to try new diet habits, improve their meal planning skill and learn new cooking methods.

The following table summarizes the main indications and contraindications of keto dieting for the average healthy individual. Medical contraindications to the ketogenic diet are generally limited to severe clinical problems, in particular disorders of fat or energy metabolism or failing organs, but sometimes pregnancy, surgeries and breastfeeding are listed as contraindications as well out of caution.

Indications	Contraindications
Low carb tolerance	Poor compliance
Large appetite	Eating out or traveling often
Neural disorders, particularly epilepsy	Performing anaerobic endurance training
Low anabolic hormone levels	Thyroid disorders: check bloodwork
Chronic inflammation	Bulking on very high energy intakes
Weight class-restricted athletes	

To the surprise of many people, the above indications make a keto diet particularly suitable for contest prep. It can partially mitigate the decline in anabolic hormone production, any potential benefits in terms of body composition are highly important and the appetite suppression and mental stability are highly desirable. Few competitors want to try it, but Menno has had good experience with the ones that do, including IFPA pro Eve Lewis.

There's one more consideration, which is purely aesthetic. During a keto diet you'll look leaner than on a higher carb diet, because you'll retain less water. This gives a dry look to your physique that most people find very appealing and it prevents some of the bloating that comes with eating carb rich meals. However, the lower resting glycogen levels also make you flatter, as your muscles are literally less full. Men are prone to interpret this as losing muscle, while women tend to overestimate the fat loss from the diet.

The low water retention also makes a ketogenic diet particularly suitable for competitive strength athletes that are restricted by their weight class. By going into ketosis at least a week pre-contest, you'll be able to carry 1-4 pounds more muscle into the show.

Cyclical ketogenic dieting

A popular variant of the ketogenic diet in fitness circles is the cyclical ketogenic diet (CKD). It is easily marketed to reap the benefits of keto dieting without having to give up carbs, but based on the above evidence and my experience, the CKD provides the worst of both worlds rather than the best. It is based on the faulty premises that carbohydrates are required for bodybuilding and that increasing insulin sensitivity has body composition benefits. The CKD leaves you in a constant state of keto adaptation where you reap few of the positive effects but many of the negative effects in terms of your mental wellbeing and dietary restrictiveness, not to mention possible metabolic inflexibility and decreased protein balance.

As we'll see in the compliance topic, it can also increase binge eating and prevent the adoption of a sustainable lifestyle.

The only study we have on the CKD is Kysel et al. (2020). It found no significant between-group differences in strength development or body recomposition between a CKD with low carbs during the midweek and carb refeeds during the weekend, compared to a moderate World Health Organization diet that was matched for energy intake (500 kcal deficit) and protein intake (~15%). However, there was a non-significant trend for better results in the non-CKD group.

Measuring ketosis

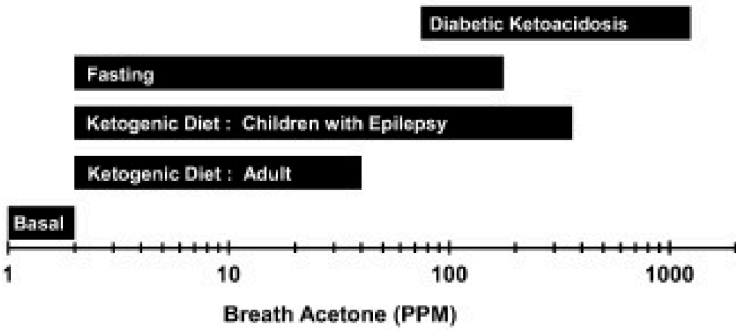
There are various ways to measure if you're in nutritional ketosis. These tools will help you to A) verify that you're actually in ketosis and B) find your individual ketosis sweet spot. Many people are best off just barely but consistently being in ketosis to increase possible carbohydrate intake, but others feel better in deeper ketosis. To find your level of optimal ketosis, you need to experiment with your net carbohydrate intake. Titrate it up or down 10 g per week and see if you feel any different and if your physical performance is affected.

Bloodwork

Direct bloodwork is ideal and there are many gadgets that can measure if you're in ketosis from 1 drop of blood from your finger. Precision Xtra is a popular and good brand, though it's also expensive.

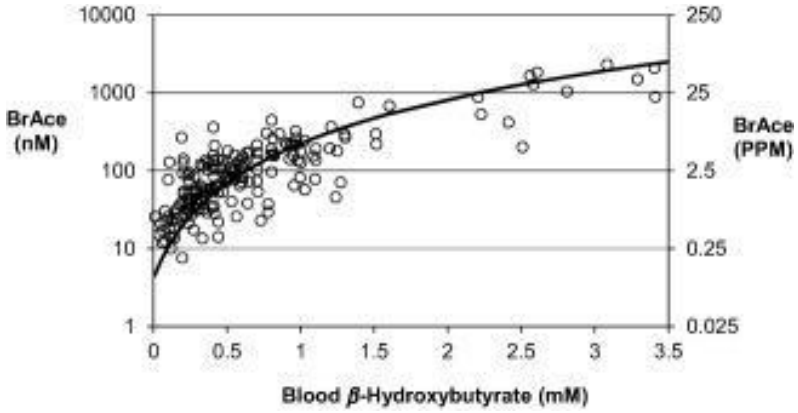
Breath analysis

Breath analyzers that measure the acetone in your breath are also generally reliable. Since you are now measuring gas acetone concentration (BrAce) rather than blood β-hydroxybutyrate, your unit of measurement becomes PPM rather than millimolar and the following reference range can be used.



Source

To convert between the different units of ketosis, the following plot can be used. Note that the relationship is nonlinear, so simple linear conversion formulas aren't accurate.



Source

Ketonix is a popular and good brand.

As a budget alternative, you can find far cheaper breath analyzers that are used for alcohol checks. Make sure they measure breath acetone, because not all of them do, especially not the new ones. They also sometimes don't distinguish between alcohol and acetone, but that's not a problem, assuming you're sober when you're measuring your level of ketosis. A bigger problem is that we have no good data on how to convert the BAC% reading they give to a level of ketosis. Anecdotally, multiplying the BAC%

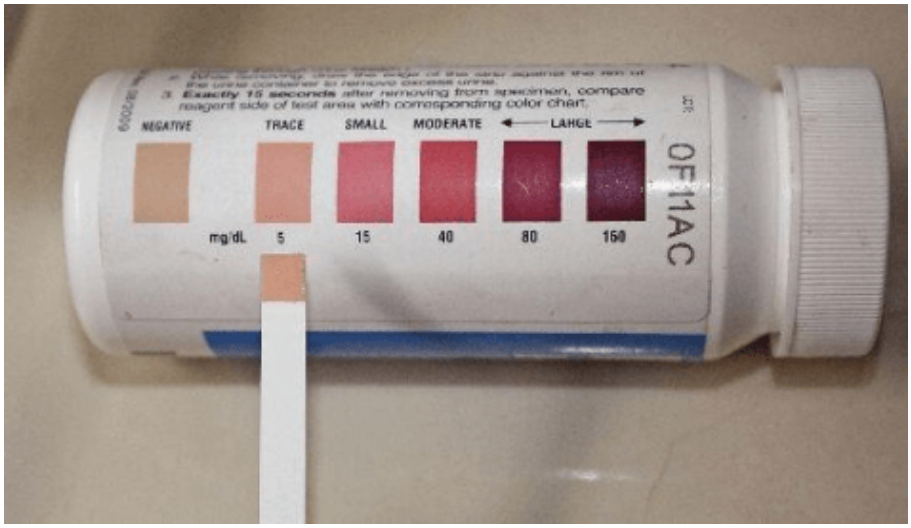
by 40 gives a reasonable estimate of blood ketone levels in nmol/L. Ketosis seem to start at a 0.01 BAC% and anything over 0.05 suggests deep ketosis.

Urine strips

Urinary keto strips AKA ketostix are generally cheapest and most readily available. Unfortunately, the correlation between ketones in the urine and the blood is imperfect and influenced by hydration status, kidney functioning and acid-base balance. Overall, urine dipsticks have poor accuracy to detect nutritional ketosis: in mild ketosis, they're barely more accurate than a coin flip to correctly identify ketosis.

Moreover, most urine dipsticks only measure the concentration of acetoacetate. As you become keto adapted, more beta-hydroxybutyrate and less acetoacetate is produced. As such, the urine test will gradually start majorly underestimating your level of ketosis.

Due to these major problems with their accuracy, urine keto strips are decidedly the worst way to measure ketosis. Their only use generally is that they provide a way to assess roughly how low you must go in net carbs at the start of the diet. Once you know, you can stop testing.



Measuring ketosis with urine strips: you pee on the strip and compare its color to the reference range provided.

When to measure

It's best to measure your level of ketosis 1-2 hours after your second or later meal of the day. Unless the meal is particularly ketogenic diet, food intake normally increases blood glucose levels and decreases the level of ketosis. Thus, if you're still in ketosis after a meal, you'll likely also be in ketosis throughout the rest of the day. Exercise and the overnight fast should increase ketone production. The morning is not a good time to measure ketosis due to the 'dawn phenomenon': many people, especially those with insulin resistance, have naturally higher blood glucose and lower ketone levels in the morning. The morning elevation in cortisol and other insulin-antagonistic hormones is responsible for this elevation in blood sugar, which is transient and normal.

Implementing a ketogenic diet

A ketogenic diet is not principally different from any other diet in many regards for strength trainees.

- You still want to get all the benefits of a high fiber intake, the benefits of which are arguably more important than those of ketosis for many people. Since your carbohydrate intake is limited, most people should stick to the following sources of carbohydrate intake to maximize the benefits of a high fiber diet.
    - Avocado (!)
    - Coconut
    - Cacao/sugar-free dark chocolate
    - Green vegetables (tip: make zucchini or spinach soup and use nori seaweed sheets or iceberg lettuce leaves as ‘wraps’)
    - Cauliflower (tip: you can make rice and ‘potato’ mash with it)
    - Mushrooms
    - Shirataki noodles (if tolerated)
- You still want to meet all your micronutrient needs (discussed in the topic on micronutrition). While you may survive on just bacon and eggs, you won’t thrive on it.
- You still want to consume a balanced fatty acid profile. In fact, it is particularly important during a ketogenic diet to consume a balanced fatty acid profile, because your fat intake is so high. Many individuals have found that the typical Atkins, eggs-and-bacon or coconut oil heavy implementation of the ketogenic diet results in skyrocketing LDL cholesterol levels.
- You still want to consume a protein intake that will maximize protein balance. You may hear of people restricting protein intake to bare minimum levels to go deeper into ketosis. This is a classic case of confusing the means and the end. Ketosis is the means to your dietary goals, usually fat loss. Ketosis is not itself

the end goal. By interfering with one of the most important aspects of the diet for strength trainees – a high protein intake – just to get deeper into ketosis – which often doesn't confer any direct body recomposition improvement at all – does not make any sense.

That said, if you've objectively measured that any further increase in protein intake reduces ketone concentrations at a given net carbohydrate intake, then you can likely decrease your protein intake to a level at which this is no longer the case. The protein intake you find this way is most likely your maximally beneficial protein intake, because the body's conversion of amino acids to glucose, rather than using the amino acids for protein synthesis, strongly suggests that your protein intake is excessive for the purpose of maximizing protein balance.

The fundamentally different aspect of a ketogenic diet is its extremely low carb nature. As discussed, however, the goal is not to minimize carbohydrate intake, as that may only increase symptoms of carbohydrate withdrawal, the risk of nutritional deficiencies and possibly reduce exercise performance. Rather, the goal is to find the *highest* net carb intake at which you reach your desired level of ketosis, as objectively measured via ketone levels.

Finding your keto sweet spot can be achieved in 2 ways: by tapering carbohydrates down or by going all-in and then increasing net carb intake. On a good ketogenic diet, many strength trainees should be able to consume ~50 g net carbs a day on training days and ~30 g on rest days while being in light ketosis, at which point they achieve a sufficient appetite suppressive effect and don't experience any loss of performance in the gym. These carbohydrate intakes are thus a good starting point for a ketogenic diet.

Then measure ketosis ~3 days into the diet to see if you're in nutritional ketosis. If not, decrease net carbohydrate intake 10 grams. If so, you can consider experimenting if you feel better in deeper ketosis or if you can stay in ketosis on a higher net carb intake. A good guideline is to adjust your daily net carb intake by ~10 grams once per week. You then monitor ketone levels and keep adjusting the net carb intake until you have found your individual ketosis sweet spot. For many people, there is no need to go into deep ketosis, but some will find going into deeper ketosis achieves greater appetite suppression and an improvement in mental performance and wellbeing.

When you've determined the individual's ketosis sweet spot, the determination of daily macronutrient needs is very straightforward.

1. Determine daily protein and calorie intakes.
2. Subtract total carbohydrate and protein intake from the daily calorie intake.
3. Fill in all remaining calories with fats.

Targeted ketogenic dieting

Targeted ketogenic dieting (TKD) is a nutrient timing strategy where most carbs are consumed in the pre- and post-workout meals. This is an effective method to increase the carbohydrate intake during a ketogenic diet at a given level of ketosis, because at these times the carbohydrates will often be used as fuel (pre-workout) or stored as glycogen (post-workout) and can potentially increase anaerobic exercise performance without taking the individual out of ketosis. (And even if the person transiently goes out of ketosis, during a workout is the best possible time for this, as appetite suppression and the potential mental benefits of ketosis aren't very relevant.)

Here's an example of TKD from one of Menno's clients. Note how no exact fat intake is prescribed, as this will vary based on the total carbohydrate intake, which in turn

depends on fiber intake. If highly fibrous foods are chosen, as recommended, total carbohydrate intake could still total ~120 g.

		Meal			
Training Days (3x)		**Pre-workout**	**Post-workout**	**Lunch**	**Dinner**
Protein Intake	153	34	34	41	44
Net carb intake	60	20	20	10	10
Kcal	3354	745	745	899	965

MCTs

Medium-chain triglycerides (MCTs), as you've learned, are absorbed by intestinal cells and transported directly to the liver via the portal vein, bypassing the lymphatic system. In the liver, the MCTs are then converted to carbon dioxide, acetate, ketones and long-chain fatty acids. As a result of their rapid absorption and oxidation, MCTs can yield more ketone bodies per calorie than long-chain triglycerides [2].

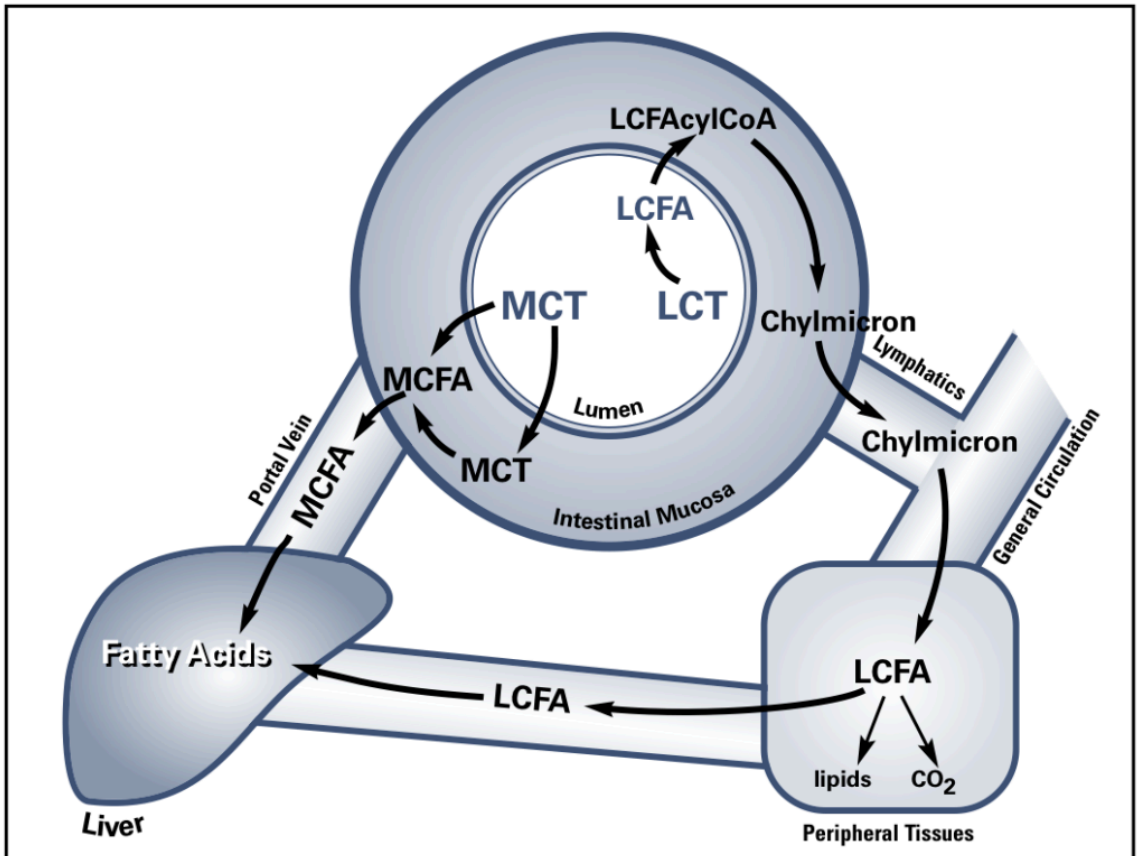


Fig. 1. Digestion and transport of fats. Note greater efficiency of absorption of MCTs versus LCTs, resulting in more rapid production of energy.

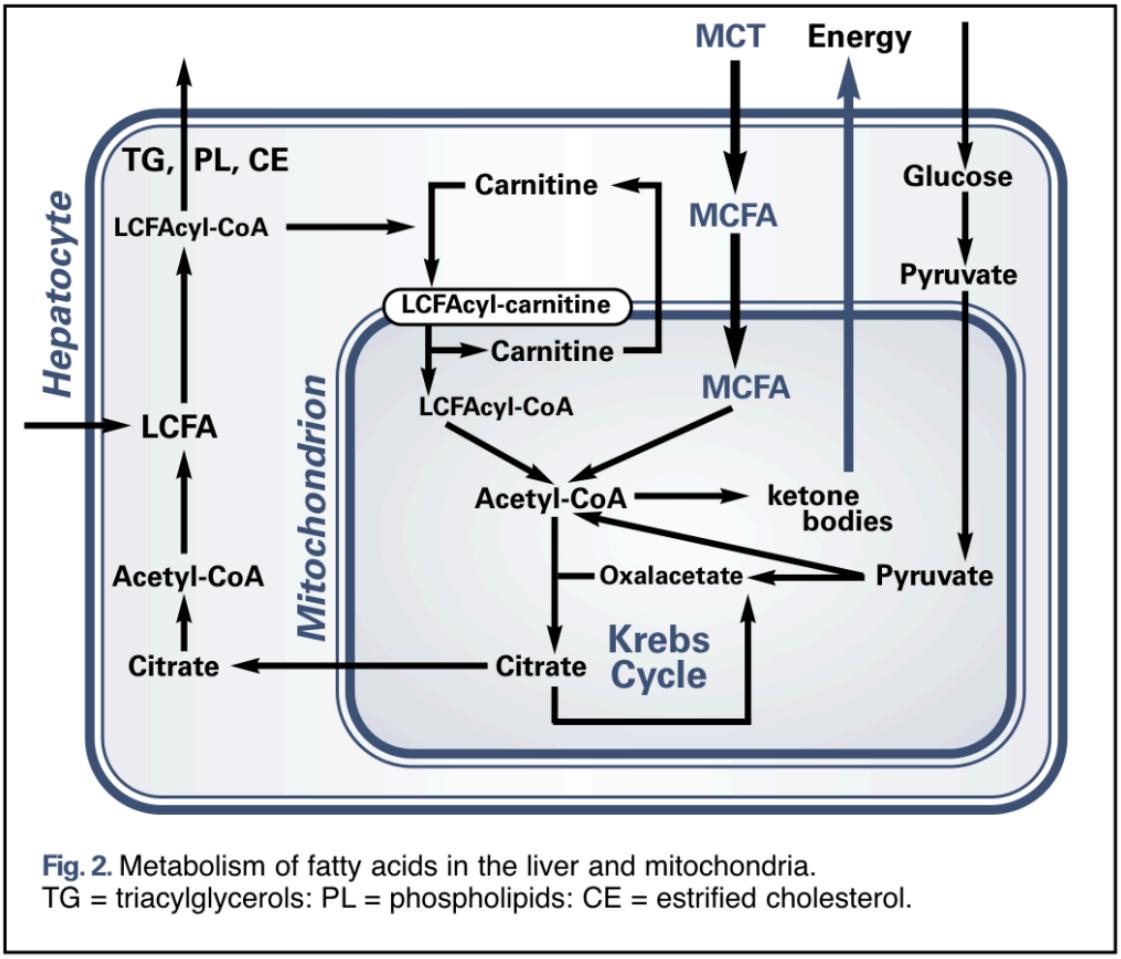


Fig. 2. Metabolism of fatty acids in the liver and mitochondria.
TG = triacylglycerols: PL = phospholipids: CE = estrified cholesterol.

Source: NutritionReview.org

MCT oils are therefore sometimes implemented during ketogenic diets to increase the level of ketosis. In other words, a diet high in MCTs can generally reach the desired level of ketosis with a higher carbohydrate intake.

That's all very well in theory, but there are only 4 medium-chain fatty acids found in food, all of them saturated:

- C6: Caproic acid / hexanoic acid.
- C8: Caprylic acid / octanoic acid.
- C10: Capric acid / decanoic acid.
- C12: Lauric acid / dodecanoic acid.

These MCTs are only present in large quantities in coconut oil with ~60% of its oil being MCT. And about half of coconut oil's fatty acids are lauric acid, which has 12 carbon atoms and is therefore right in between a medium- and long-chain fatty acid. As such, coconut oil is not nearly as effective as pure MCT oil to induce ketosis and satiety.

Milk fat has a meh-ok 10-20% MCT content and that's about it in terms of foods you may want to consume.

Due to the wonders of modern technology, we can also create pure MCT oils and these are very popular in the paleo community. MCT oil raises ketone levels substantially more than coconut oil. Presumably as a result of that, MCT oil is even more satiating than coconut oil, which some research already finds to be more appetite suppressing than other oils [2], but other research doesn't. MCTs also have a greater thermic effect than other saturated fatty acids in most research.

There's also weak evidence that MCTs may improve muscle growth [2], but there's no known mechanism by which these benefits could occur and the supporting research is methodologically poor.

The story so far makes for a great sales pitch for MCT oils. However, there's a huge logical problem with the benefits of MCT oils: the benefits of increased energy expenditure and of a lower ad libitum energy intake because of a lower appetite come with the cost of increased energy intake in the oil. You're consuming calories to consume fewer calories. It's almost ironic. The thermic effect of food is normally only a fraction of its energy content, so it never makes sense to consume anything because it's thermogenic: you always end up with net energy intake. That leaves appetite suppression. Consuming MCT oil with a high energy intake can be worth it if it's so

appetite suppressing that your subsequent ad libitum energy intake will tend to end up lower than if you hadn't consumed the oil. For this to occur, the MCT oil must be far more satiating per calorie than the rest of your diet. Let's see if this is the case.

Kinsella et al. (2017) looked at the effect of consuming 205 kcal of MCT oil, coconut oil or vegetable oil for breakfast and measured subsequent ad libitum energy intake. Compared to the vegetable oil, both 'keto oils' indeed reduced total daily energy intake, though coconut oil did not significantly decrease energy intake during lunch. Metin et al. (2022) also found no significant effect on lunch energy intake of consuming coconut oil compared to olive oil at breakfast. Coconut oil decreased energy intake by 280 kcal; MCT oil reduced it by 428 kcal. So, the coconut oil group consumed 205 kcal to achieve a 280-kcal reduction in energy intake. This was a marginally positive trade-off, but this was in a diet of processed sandwiches with tuna mayonnaise, ham and cheese. People eat substantially less food on a whole food diet, which means the coconut oil trade-off would most likely be negative: you consume more calories than you save later in the day if you eat ad libitum. On top of that, you effectively wasted 205 kcal on food with almost no micro-nutritional value, fiber or protein. Participants also regarded the coconut oil as quite unpalatable, even less palatable than vegetable oil (try it and you'll understand). That's a double loss.

For MCT oil, the trade-off may be positive. Their net energy balance decreased by about 200 kcal. This may still end up slightly positive in a whole-foods based diet. However, this 'benefit' of MCT oil comes with a major caveat: nausea. Several participants complained of nausea after the MCT oil. You eat less when you're nauseous. Large amounts of MCTs are well known to cause nausea and other digestive problems, even to the point of vomiting. So is it really the satiating power of MCT oil or just its nausea and unpalatability that makes you want to eat less?

Smith-Ryan et al. (2019) conducted an RCT in which the participants replaced their regular breakfast with an MCT shake. The MCT shake tended to reduce daily energy intake and improved satiety, but it didn't increase energy expenditure significantly and the effects were not enough to achieve significant fat loss over 8 weeks.

While many studies support coconut oil is more satiating than oils like long-chain triglyceride oils (LCTs) and MCT oils are in turn more satiating than coconut oil, not all studies find benefits. The satiating effect of coconut and MCT oils is quite inconsistent and does not consistently lead to fat loss [2]. For a full research overview, see the link below.

➢ Research overview

The effect of coconut and MCT oils on satiety

In addition to the problem of its high caloric content, MCT and coconut oil also have ambiguous health effects. While some research finds beneficial effects on people's cholesterol profile with an increase in only HDL-cholesterol, those studies are confounded by fat loss except Khaw et al. (2018), which found coconut oil was comparable to olive oil in health benefits [2, 3]. Other research and anecdotal bloodwork reports find considerable increases in LDL-cholesterol. All medium-chain fatty acids are saturated, so it's generally not a good idea to make those your primary fat source (see course module on dietary fat).

A different niche use of MCT or coconut oil is to reduce the keto flu. A study by Harvey et al. (2018) found a trend for MCT oil to speed up the achievement of initial ketosis and reduce the symptoms of the keto flu compared to sunflower oil, but most comparisons did not reach statistical significance and several participants experience

digestive side-effects, such as abdominal pain. As such, it may be worth trying some recipes with coconut oil during the keto flu period to get it over with as soon as possible, but spending money and calories on MCT oil may not be worth it unless your keto flu is particularly bad.

In conclusion, most people are better off with pure intermittent fasting or whole foods than gimmicky oils. They're satiating and thermogenic for oil, but any kind of oil is arguably a waste of calories: it's not as satiating as fibrous, protein-rich whole foods, most people don't find it tasty and it's almost entirely devoid of micronutritional value. That said, if you happen to have recipes that work well with coconut (or possibly MCT oil, but the nausea is a major problem) and you need some more saturated fat in your diet, by all means fit some coconut (oil) in your diet. It may suppress your appetite and increase your expenditure a bit compared to other oils and butters. But there's no need to go out of your way to, say, put MCT oil in your coffee and chug down hundreds of calories of oil. Consuming large numbers of calories to go into a metabolic state with the primary purpose of reducing energy intake largely defeats the purpose of a ketogenic diet.

Exogenous ketones

Exogenous ketone supplements have emerged as a magic bullet to get the benefits (if any) of ketosis without having to follow a low-carbohydrate diet. This sounds nice in theory, but just consuming ketones to raise blood ketone levels does not achieve the same metabolic stat as a low carbohydrate diet, as glucose is still available and keto-adaptation has not taken place.

Moreover, for fat loss exogenous ketones face the same problem as MCTs, as many exogenous ketone supplements have hundreds of Calories. It makes no sense to consume a good deal of calories to get into a metabolic state with the purpose of limiting energy intake. Consuming exogenous ketones does not affect our body composition, regardless of whether we're in energy deficit or at maintenance intake.

Performance wise, exogenous ketone supplements don't seem to live up to the hype either [2]. They cause a shift from glucose to fat oxidation as the fuel source of exercise, but the resulting effect on performance isn't favorable.

- Leckey et al. (2017) found that exogenous ketone supplementation did not improve endurance cycling performance: it even significantly impaired performance in professional cyclists compared to a placebo. This may have been related to digestive discomfort, as this is a common complaint of exogenous ketone supplements during exercise.
- O'Malley et al. (2017) also found that exogenous ketone supplementation **decreased** average power output during high intensity cycling performance and the speed at which they could complete a longer time trial. Ketones decrease blood glucose levels and may impair glycolysis, which without keto adaptation may leave the body unable to meet the energetic demands of high intensity exercise.

- Waldman et al. (2018) found no effect of exogenous ketone supplementation on repeated Wingate power output.
- Sonnenburg (2018) found that exogenous ketones did improve cycling time to exhaustion at 70% of VO2max but not 10k trail time in male varsity athletes. This was again compared to a placebo. A more relevant comparison would have been versus an isocaloric glucose beverage. The authors speculated that exogenous ketones only improve performance in between 50-70% of VO2max. However, there is no plausible rationale for why this would be the case.
- Evans et al. (2018) found that exogenous ketone supplementation did not improve muscular efficiency or decrease perceived effort at any intensity ranging from 30 to 80% of VO2peak in trained cyclists.
- Evans et al. (2019) found no benefits of a ketone mono-ester supplement on running times.

That leaves cognition. Many people rave about how good exogenous ketone supplements make them feel. What they fail to realize, is that the clever marketing teams behind the exogenous ketone supplements have sneaked in caffeine in the supplements. Is it the ketones or the caffeine that makes you feel more awake and energetic? Caffeine is well established to have this effect, whereas exogenous ketones are not.

- Indeed, Waldman et al. (2018) found that exogenous ketone supplementation did not improve cognition in students.
- Short et al. (2017) found no beneficial effects of an exogenous ketone supplement on cognition, even though there was caffeine in the supplement.
- Evans et al. (2019) also found no benefits of a ketone mono-ester supplement on reaction times or a multi-tasking test.

- Other research, such as that by O'Malley et al. (2017) also indirectly shows that you don't feel anything from exogenous ketones, as the subjects were unable to tell if they were in the placebo or ketone supplement condition.

In short, exogenous ketone supplements seem to be a waste of calories and money that may even impair performance.