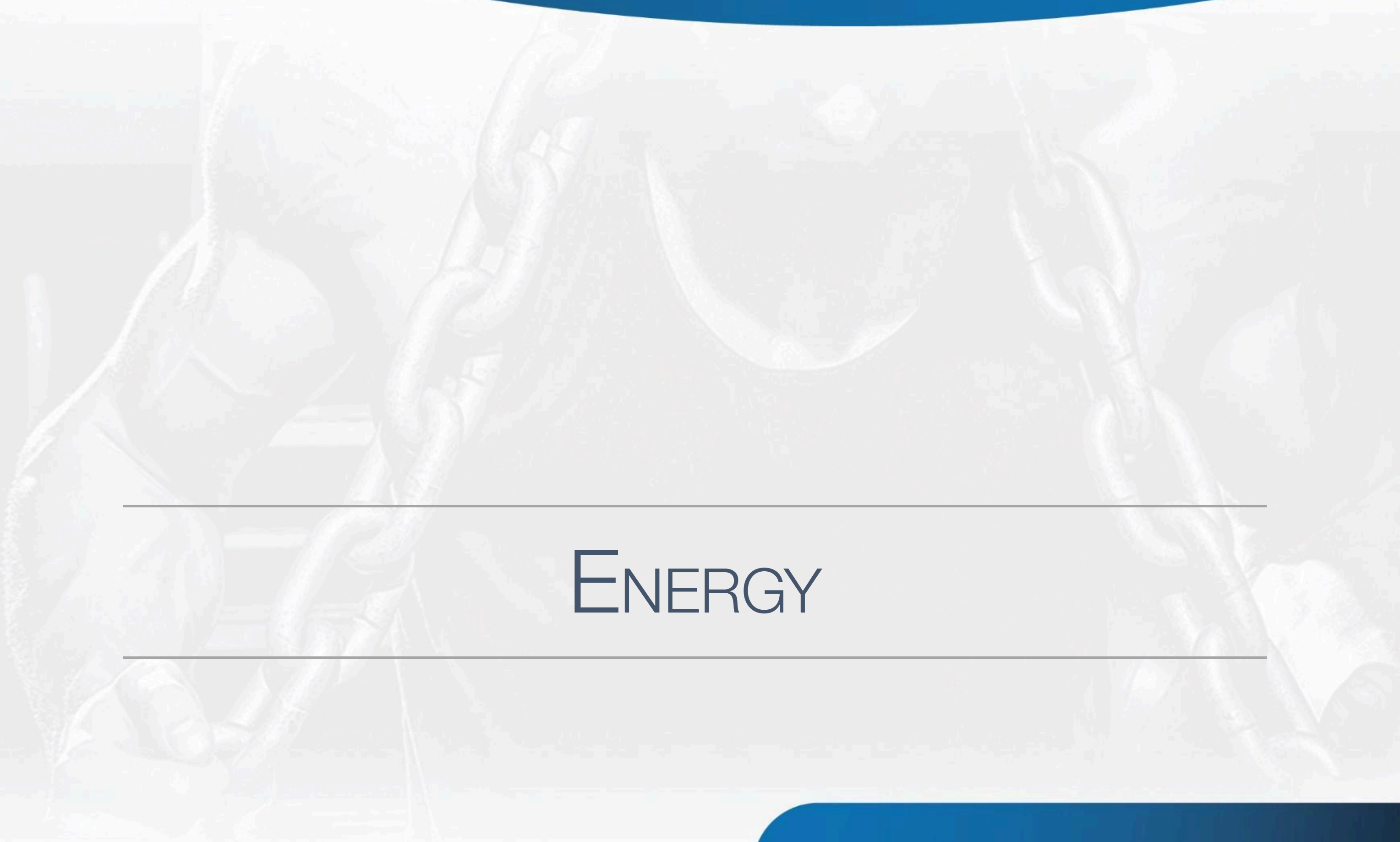

Energy

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Contents

➢ Lecture [optional]

Energy

Note for students: We start with this module not only because it's one of the most important but also because it's one of the most difficult ones to understand for people that don't like math, which is most people. Take your time, ask questions about what you don't understand and use the provided calculators. Good luck!

- *Menno*

Despite all the controversy surrounding weight loss, science has come exceedingly close to having mathematical proof of how exactly weight loss occurs. This proof comes from the laws of physics, specifically the first law of thermodynamics ('movement of energy'). To understand this law, we first need to understand energy.

Energy

The human body, just like all other objects, contains energy. You may ask what energy is. It's a good question. And you'll hate the answer. Energy, like gravity, is not an observable physical entity. It is a theoretical entity that explains how nature works. We invoke the existence of energy to explain movement and chemical reactions. This doesn't make our understanding of energy any less perfect though. From a Bayesian perspective, the highest level of understanding is perfect predictive power. If you can predict and explain how a system works, you understand it. Everything else is just semantics. In this light, we can explain energy very well. We can even calculate it precisely.

Calories

Calories are a measurement unit of energy, like meters are a measurement unit of distance. To show the arbitrary nature of energy, a calorie is equal to the approximate amount of energy needed to raise the temperature of one gram of water by one degree Celsius at a pressure of one atmosphere.

When we speak of Calories in nutrition, we are actually referring to kilocalories. A physical (thermal) calorie is only one-thousandth of a nutritional kilocalorie. To distinguish the thermal calorie in physics from the nutritional Calorie, the nutritional Calorie should officially be written with a capital C. Despite official conventions, many people in the field of nutrition refer to kilocalories as calories with a small c. Be sure to abbreviate calories as kcal or Cal, not cal.

1 nutritional Calorie = 1 kcal = 1 Cal = 1000 calories = 1000 cal

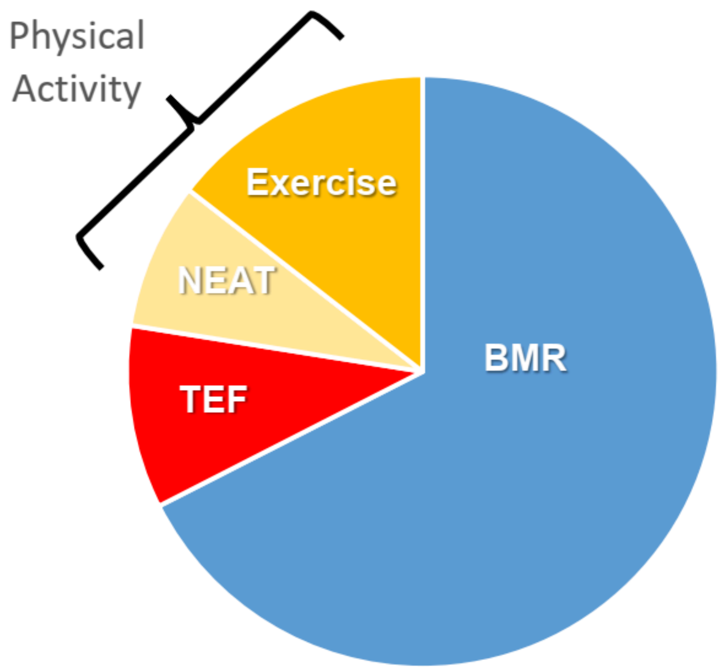
In scientific papers you may also come across another measure of energy, the joule (or kilojoule). You can simply convert this to calories using the formula below, just like you can convert pounds to kilograms. For example, if you have a food label that says 104.6 kJ, that's equal to 104.6 / 4.184 = 25 kcal.

1 kcal = 4184 joules = 4.184 kilojoules (kJ)

Why does your body need these calories?

Energy expenditure

The body needs energy to move, produce heat and perform chemical reactions. The following graph summarizes the contributions to energy expenditure of the average sedentary person.



Components of daily total energy expenditure. BMR = basal metabolic rate; NEAT = non-exercise activity thermogenesis; TEF = thermic effect of feeding. [*Source*]

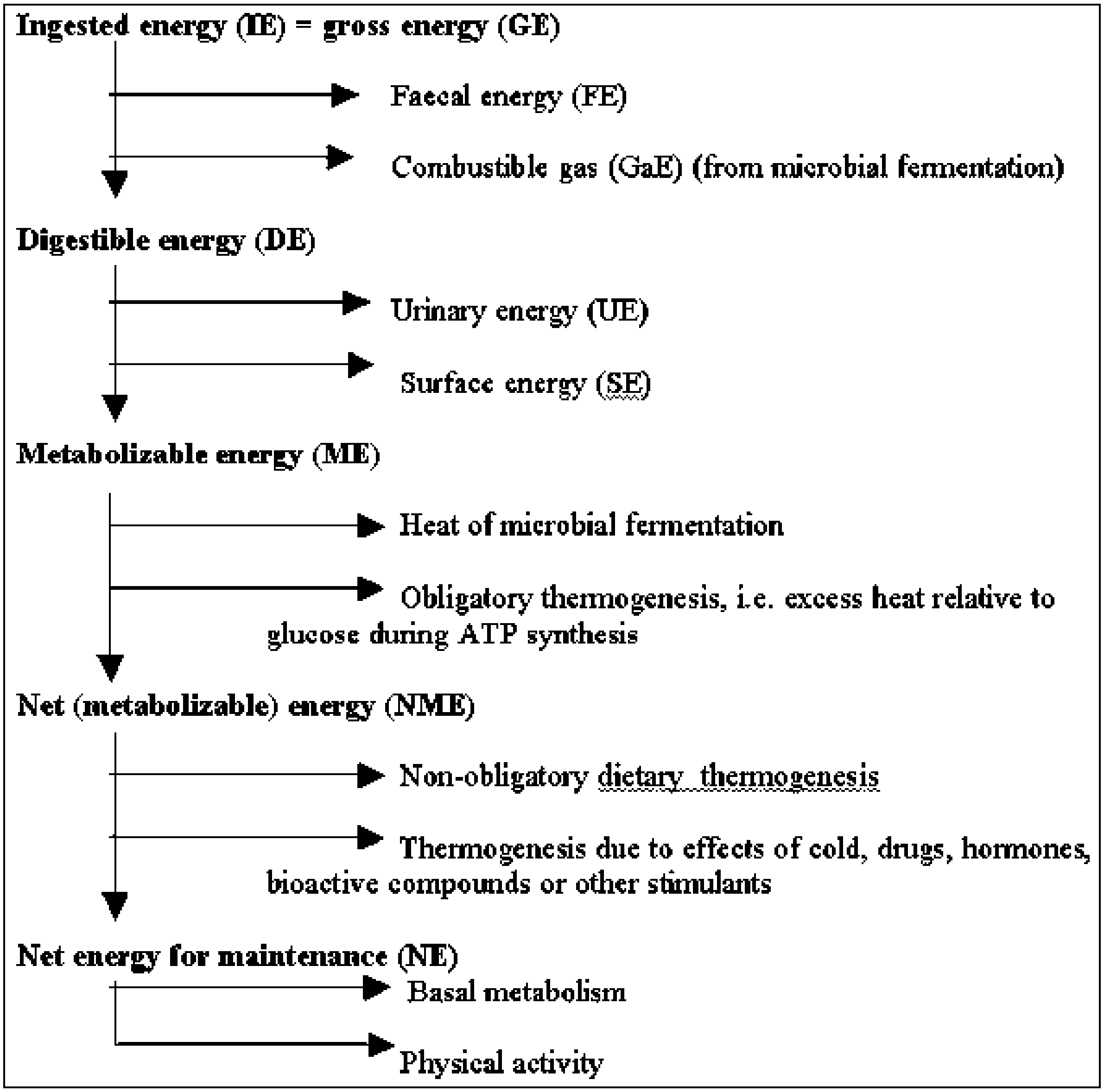
We'll get into how to estimate these components later. For now, we're only focused on the total.

Energy intake

Energy comes into the body in the form of food. We can measure the total (combustible) energy content of a food in a reaction chamber using a method called bomb calorimetry. Not all energy from food is available for the body to use for energy expenditure (metabolizable energy), as summarized in the following graphic. While the body is very efficient in harvesting energy from food, some of it escapes via various pathways.

1. The body cannot digest or absorb all total gross ingested energy content from food. Some food components go through the digestive system and right out in your feces or gas.
2. Of the digestible energy, the body cannot catabolize all of it. Some is lost as waste in your urine. A little surface energy also escapes.

Together these losses amount to 3-12% of energy intake with 1-2% urinary energy loss and 2-10% fecal energy loss. What remains is actual metabolizable energy: energy that the body can use to produce heat, movement or chemical reactions.



Source: [FAO FOOD AND NUTRITION PAPER 77]

Fortunately, scientists have come up with calculations to estimate the metabolizable energy (ME) content of food. The most commonly used estimates of metabolizable energy today are from the Atwater general factor system. While not perfectly accurate for all food types, its beauty lies in its simplicity. The Atwater factors are simply 4 kcal per gram of protein or carbohydrate, 9 kcal per gram of fat and 6.9 kcal per gram of alcohol. The Atwater metabolizable energy estimates are very close to the best estimates of net metabolizable energy. Only protein differs considerably at 3.2 kcal/g NME vs. 4 kcal/g ME. Food labels in developed countries generally already use estimates of net metabolize energy or food-specific Atwater factors, so they should be very accurate.

With these estimates we can easily and quite precisely calculate how much metabolizable energy intake someone has based on what they eat, i.e. calculate energy intake from someone's food log.

Thermodynamics

Energy cannot be destroyed. It can only be transformed into a different form. There are many forms of energy. For our purposes, the following are most important:

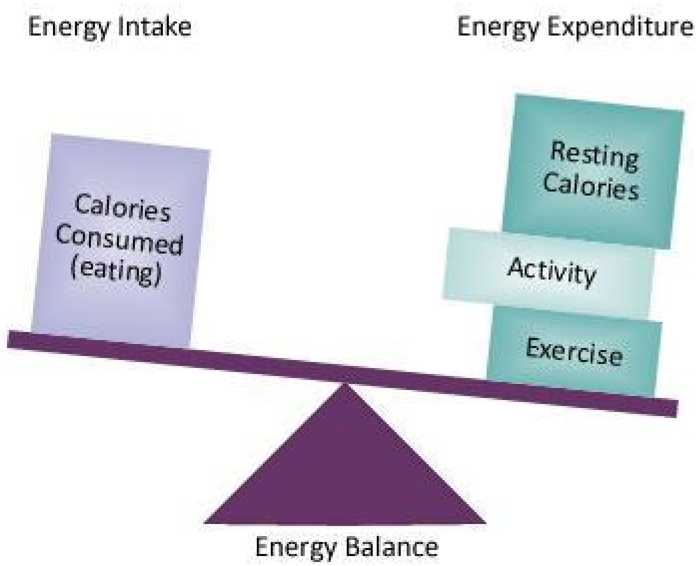
- Chemical energy is the stored form of energy in food and your bodily tissues.
- Kinetic energy is the energy of moving objects. When we 'burn' bodily energy to move, chemical energy is transformed to kinetic energy. Kinetic energy produces mechanical work. In other words, the purpose of muscle cells is to convert chemical energy into mechanical work so we can move.
- Thermal energy is the energy we feel as temperature. When we 'burn' bodily energy, chemical energy is transformed to thermal energy. This transformation is called heat production.

The above basically summarizes the first law of thermodynamics ('movement of energy') and the principle of conservation of energy.

Energy balance

Based on the thermodynamic laws, we can formulate the principles of energy balance.

- If you consume more calories than you expend, your body stores energy.
- If you expend more calories than you consume, your body loses energy.
- If you are in energy balance, your body maintains the same amount of energy.



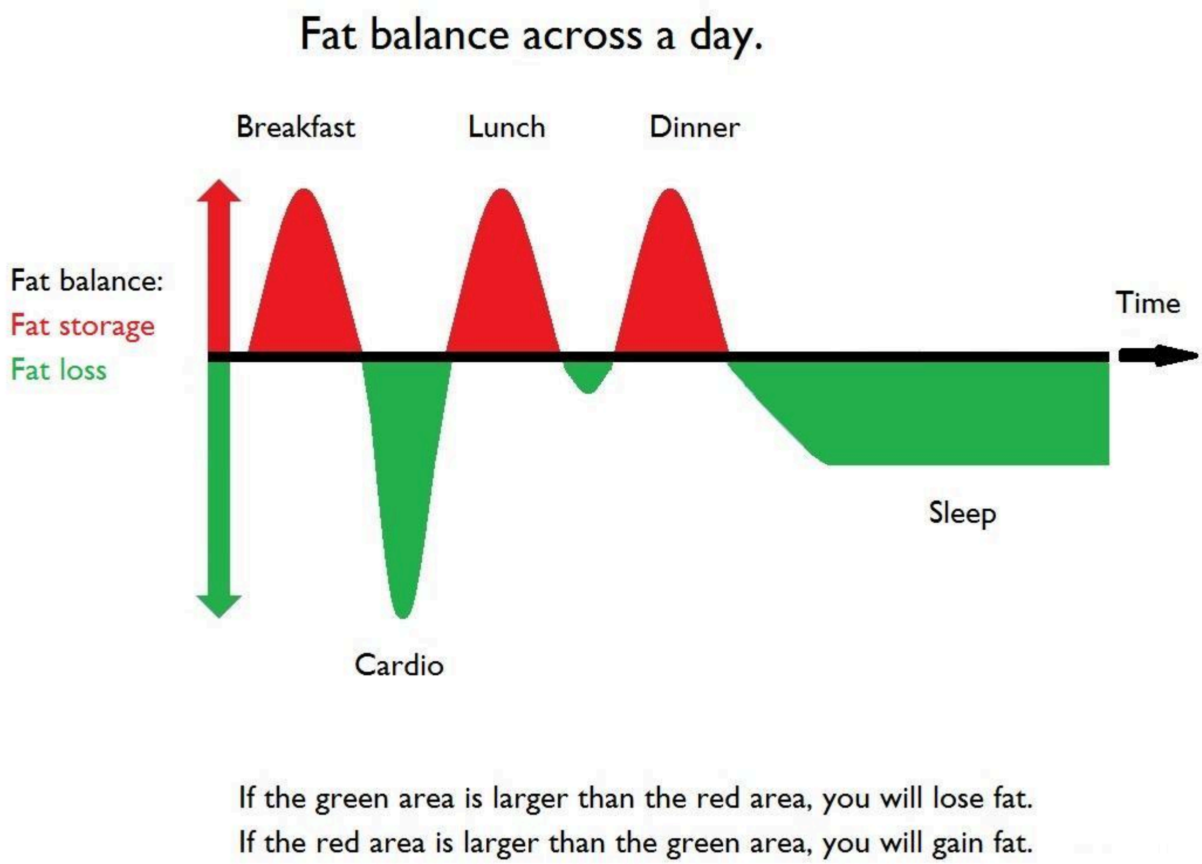
We can also state the energy balance principle as a mathematical formula:

Change in body energy = Energy intake – energy expenditure

Substrate metabolism

Thinking about energy balance is far more useful than thinking about acute substrate metabolism, like ‘fat burning’. Your body has a variety of ways to produce energy from the 3 major macronutrients: carbohydrates, protein and fat. What happens at any moment of time is only a snapshot that does not necessarily represent the energy flux over time.

Here’s an example of fat balance across a day to show that cardio does not make you lean unless it results in negative energy balance. Throughout the day, you will at different points of time be storing and losing fat. The only thing that ultimately matters is the total balance, which comes back to energy balance, since your body can convert carbohydrates and protein to fat and store them as energy.



Note that this image already shows actual fat losses and gains. If you are simply looking at acute fat oxidation, the link to total changes in fat mass over time is even weaker. For example, during a ketogenic diet, your body will be burning a ton of fat all throughout the day. This is easily advertised as 'the keto diet turns you into a fat burning machine', but it doesn't mean you'll actually lose fat mass. Fat is just the substrate being burned, because it is abundant in your diet. Your body will now be burning relatively little of its own fat. It will only burn its own fat if dietary fat is insufficient to cover the need for fat as fuel. So once again you're back to looking at energy balance to determine actual weight change.

The same applies to low fat diets. Your body generally doesn't convert protein or carbohydrates to fat and prefers to store the fat from your diet as fat. However, even if you don't consume any fat, if you consume more protein and carbohydrates than your body needs for energy expenditure, they can be converted to fat. Even if they are stored as glycogen, that means fewer carbs (short for carbohydrates) will be stored as glycogen later on, which means more of them will be converted to fat or used as energy, in which case less fat is burned. In every scenario, you end up looking at energy balance to determine whether your body has to burn its own energy.

In conclusion, when determining the effects of any diet on your weight and body composition, always keep total energy balance over time in mind, not just acute substrate metabolism. The laws of physics do not bend. For any dietary intervention to improve fat loss, it must either

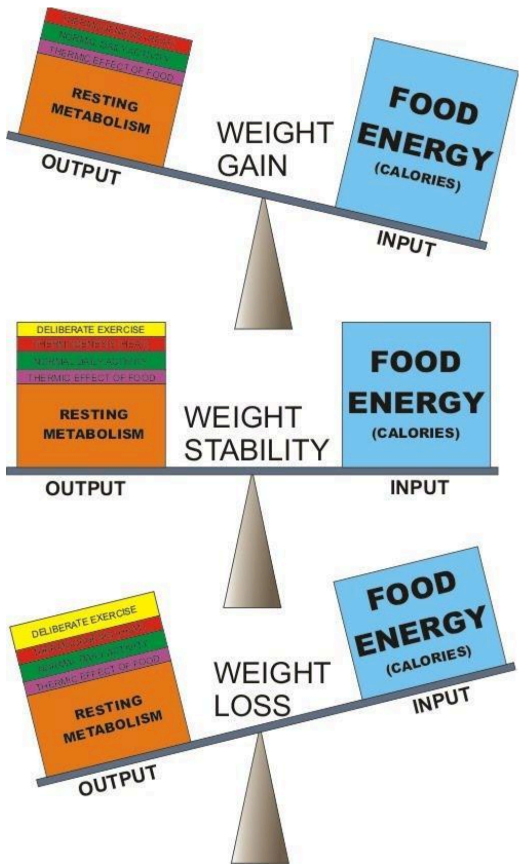
A) increase energy expenditure or

B) decrease energy intake or

C) improve nutrient partitioning. What's this? This brings us to the next topic.

Energy vs. mass

The energy balance principle is often equated with weight balance, as in the figure below.



Energy and mass changes do indeed correlate. For example, losing energy from the body logically equals losing mass under the assumptions that 1) the end products of the energy burning process, such as carbon dioxide and water, leave the body, and 2) everything else in the body stays equal. In this case, the stored chemical energy in tissue is lost from the body and transferred to the outside world while producing heat or movement. Similarly, gaining bodily energy from the chemical energy in food normally results in higher body mass.

The above assumptions are crucial, but they're often forgotten in fitness circles, resulting in the belief that you must be in energy surplus to gain muscle and you must be in energy deficit to lose fat. You will see the equation between weight and energy even in some academic textbooks and scientific papers, like this Nutrition Reviews paper, yet it is incorrect. The first mistake is that not all bodily mass corresponds with stored energy. In practice the body's weight and total energy level correlate strongly in untrained individuals over the long run, but there are many ways to change your weight while remaining in energy balance.

- When you go on a ketogenic maintenance diet, you will almost certainly lose body mass without being in a deficit. The lost bodyweight will mostly be water as a result of the lower carbohydrate content of your diet and changes in your body's electrolyte balance.
- Foods that cause abdominal bloating and water retention can similarly cause weight gain without a caloric surplus.
- Not to mention diuretics, the menstrual cycle, drugs, changes in mineral consumption, colon cleanings, creatine, etc.

The above examples are relatively trivial in the grand scheme of weight loss over the course of years, so it is understandable that researchers who only study individuals that don't even lift equate energy with weight.

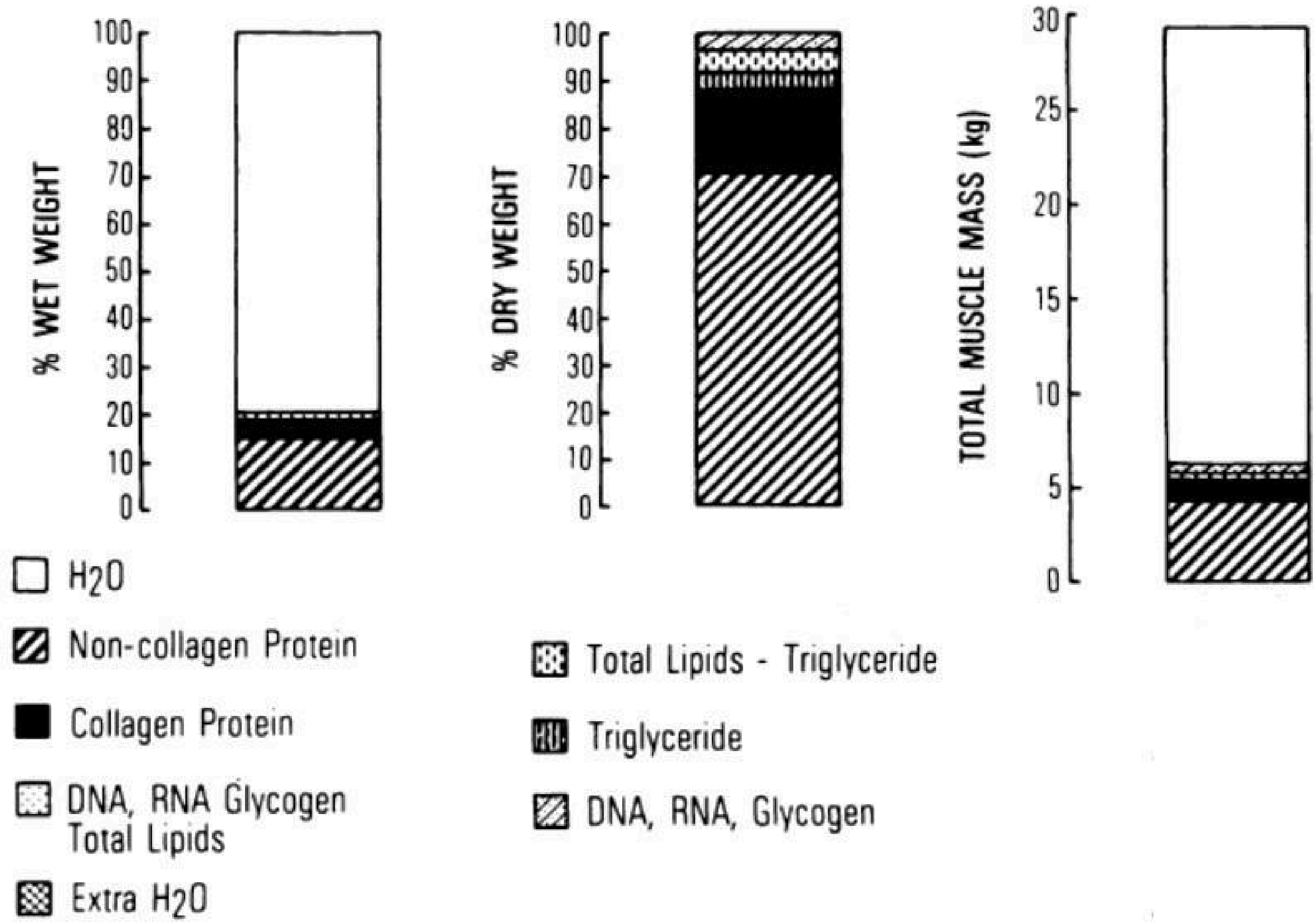
However, there's a second problem with equating mass and energy that's very important for strength trainees: nutrient partitioning that results in changes in body composition. The body can direct calories towards lean body mass, which includes muscle mass, and fat mass independently at the same time. Energy storage and oxidation are occurring throughout the body at various rates, as do changes in fat and lean body mass. Where the body directs its energy is called calorie partitioning or, more generally, nutrient partitioning. We can express the resulting change in fat and muscle mass as a P-ratio.

P = 0 means all weight loss comes from fat.

p = 1 means all weight loss comes from lean body mass (protein).

Your body is most likely breaking down and building fat as well as muscle mass right at this very moment in some parts of your body. All tissues are constantly in flux. If your body couldn't modify certain lean tissues without the total body being in energy surplus, you could not heal from any injury or disease in energy deficit, which would obviously be an evolutionary disaster. Because of nutrient partitioning, your body can build muscle when you're losing fat at the same time. The conservation of energy law only means that you must gain net total energy in energy surplus and lose net total energy in a deficit. The *total energy content of the body* is dictated by thermodynamics, but the *body composition* corresponding to that level of energy storage is not. Lean body mass and fat mass can both change in different directions, as long as the total sum of their energy change equals your energy balance. It is possible to gain muscle at the same rate as you're losing fat and you'll end up weight stable. Total weight doesn't change then, but there is still body recomposition.

The body does need substrate to build muscle mass of course. You need building blocks to build a house. Let's look at what exactly the body needs. Heymsfield et al. (1982) were kind enough to cut up some dead people for us, so we've aggregated their results from the healthy control group in the following image. This is the composition of human muscle tissue. ('Extra' water refers to excess water here, i.e. overhydration or bloating.)



So what do we need to build muscle mass?

1. Lots of water (H_2O). You can drink plenty of that during a cut, so no problems there.
2. Several kinds of protein. You can eat enough protein on a cut, so no problems here either. For the DNA and RNA, we also need nitrogen and phosphate, but we can obtain those from dietary protein.
3. Glycogen and triglycerides. This basically just comes down to energy, because glucose and fat are non-essential nutrients that the body can create itself. We

need a lot more energy too, because the protein synthesis for the muscle building process is an energy costly process itself.

In short, we need protein, water and energy. Where do we get the energy? Easy. Your body has plenty of that. Let's take Menno in average photoshoot condition at about 87 kg (191.8 lb), 6% body fat. People think of this conditioning as 'having almost no fat', but the truth is, there's still plenty of fat even then: 5.2 kg (11.5 lb) to be exact. If we convert that to metabolizable energy (discussed shortly), the body still has over 49,000 kcal in storage. That's plenty to build pounds and pounds of muscle without even considering you're still consuming energy in your diet as well. Only when you approach essential body fat levels and you're in energy deficit, does the body truly not have any energy substrate to build muscle without catabolizing functional tissues.

In conclusion, energy balance and mass balance correlate well over the long run in untrained individuals, but they are not the same and trained individuals can experience body recomposition that distorts the relationship between energy balance and mass changes. As long as your body has sufficient stimulus to build muscle mass, which it has if you optimized your training program, it has both the means and the will to build muscle mass while simultaneously losing fat.

Body recomposition

Theory is nice and all, but what happens outside the laboratory? Do people actually manage to build muscle while losing fat?

Yes, they do. For example, in one study, overweight (26% body fat) police officers starting a weight training program lost 4.2 kg (9.3 lb) of fat and gained 4 kg (8.8 lb) of lean body mass in 12 weeks.

Ironically, it's usually the self-proclaimed science-based skeptics that say you can't build muscle and lose fat at the same time. Yet people in dozens if not hundreds of studies lose fat and build muscle at the same time when they start training, even sometimes when they only do endurance training [e.g. 1, 2, 3, 4]. Young, old, healthy, unhealthy, male, female, obese, lean, they all can achieve body recomposition. Even on mediocre training programs with crappy diets with suboptimal protein intakes. Even elderly men and women over 60 years old generally gain around 1.8 kg (4 lb) of lean body mass with the same amount of fat loss in 12 to 16 weeks [e.g. 1, 2].

But all these people were barely trained. How about trained individuals? There are also many studies demonstrating body recomposition is possible in trained individuals, though it's substantially more difficult to realize than in untrained individuals.

One study looked at elite gymnasts. These were national level athletes with a training volume of 30 hours a week. They could do 17 pull-ups where their *chest* touched the bar. Many people can't do one. They were put on a 1971 kcal, ketogenic diet, which is low for athletes training over 4 hours a day. Their fat percentage of 7.6% dropped to 5% – lower than many bodybuilders in contest shape – in 30 days. Even under these conditions, they gained 0.4 kg (0.9 lb) of lean body mass. And don't forget they must have lost a considerable amount of glycogen and water eating just 22 grams of carbs a day.

Similar findings of positive body recomposition have been found in elite athletes of various other sports, including elite rugby players and Division 1AA football players already squatting over 174 kg (382 kg) and benching over 131 kg (289 lb).

Even some women competing in the IFBB gained muscle during contest prep during a study that carefully monitored their hormone levels. In Menno's clients with access to reliable body fat measurement techniques, such as DXA scans, a few gained muscle all the way up until the last few weeks before their contest. In truly advanced individuals, body recomposition is not expected in contest prep though.

Here's an example of one of Menno's clients that had over 20 years of training experience and was already benching 107 kg (235 lb) for 5 reps before the coaching. He performed a DXA scan every ~3 weeks during my coaching. In 2 months and 18 days, he lost 3.1 kg (6.7 lb) of fat while gaining almost exactly the same amount of muscle. His weight during the last scan was within 8 grams of his weight when we started. So this is an example of virtually perfect body recomposition. You can find the anonymized DXA scan overview here and his progress photos below.

14 % 13.4 % 12.2 % 10.3 %

Gaining muscle on a weight loss diet is not only possible, it should be expected for almost all novices, many intermediates and occasionally advanced trainees on an optimized program. As long as the stimulus for muscle growth is carefully designed and customized, your body will find a way to get bigger. Your body is not the enemy. It is a miraculous survival machine that adapts to the stress you impose on it. When you understand it, you can control it.

So screw the naysayers. When you don't believe what you want is possible, you have defeated yourself before you even began.

Calculating energy balance

Not only can lean body mass and fat mass change independently, with the metabolizable energy densities of fat and lean body mass from Hall (2008) we can precisely calculate the deficit or surplus someone was in based on that person's body composition change. The following table lists the metabolizable energy densities of glycogen, protein, fat and average lean body mass. Note that the human body's energy densities of glycogen, protein and fat are not the same energy densities as the Atwater factors of total energy in food, which are 4 kcal per gram of protein or carbohydrate and 9 kcal per gram of fat.

Tissue	Metabolizable energy density (kcal/kg)
Glycogen	4207
Protein	4708
Fat	9441
Lean body mass	1816

So someone who gained 3 kg of lean body mass and lost 1 kg of fat **must** have been in an energy balance of 3 × 1816 - 9441 = -3993 kcal by physical law, i.e. an energy deficit.

When you have reliable body composition measurements of someone at 2 or more time-points, you can use the following calculator to determine their exact energy balance based on the mathematics in the above article. Note that this calculator is *only* useful if you have 2 comparable, reliable measures of body composition over time. We discuss which body composition measurements are reliable in the course module on measuring progress and optimizing energy intake.

➢ PT Toolkit

Energy balance calculator

(Don't confuse this with the energy *intake* calculator.)

3500 kcal per pound of weight loss?

You don't need to lose a full 9441 kcal to lose a kilo of adipose tissue, which is what most people call a kilo of fat. With the estimate that adipose tissue is only 87% pure triglyceride with the rest being water and some protein, it takes about 8260 kcal to lose a kilogram of adipose tissue. Many textbooks still say it takes only 7000 kcal to lose a kilo of fat, but this is false. Researchers have estimated in the average individual it takes about 3500 kcal to lose a pound of *weight* with the assumption of a certain P-ratio. The 3500-kcal figure assumes approximately 20% lean body mass loss. If you want to lose a kilo of pure adipose tissue, you need a net energy deficit of about 8260 kcal.

Gaining weight in a deficit

Not only is it possible to gain muscle in an energy deficit, you can even gain weight because lean body mass has so much less energy per kilogram than adipose tissue. For example, here's the DXA scan progress of one of Menno's clients. Note how he gained 2.8 kg (6.2 lb) of muscle while losing 0.9 kg (2.1 lb) of fat in under a month. Here's the full anonymized DXA scan report of his progression for those interested.

Body Composition History (Region: Total)

		Change vs.			Change vs.			Change vs.			
Measured Date	Total Mass (lbs)	Baseline (lbs)	Previous (lbs)	Fat Mass (lbs)	Baseline (lbs)	Previous (lbs)	Lean Mass (lbs)	Baseline (lbs)	Previous (lbs)	Total Region %Fat (%)	BMC (lbs)
03/06/2015	181.2	baseline	-	29.9	baseline	-	143.4	baseline	-	16.5	7.9
04/17/2015	177.5	-3.7	-3.7	24.2	-5.7	-5.7	145.4	2.0	2.0	13.7	7.9
05/15/2015	181.6	0.4	4.1	22.1	-7.8	-2.1	151.6	8.2	6.2	12.2	7.9
08/19/2015	178.9	-2.3	-2.7	19.1	-10.8	-3.0	151.7	8.3	0.1	10.7	8.0
10/12/2015	182.7	1.5	3.8	20.1	-9.8	1.0	154.5	11.1	2.8	11.0	8.0

BMC = Bone Mineral Content

Skeptical? Weight gain in energy deficit also occurs in some research. For example, in Maltais et al. (2016), one group lost 1.1 kg (2.4 lb) of fat while gaining 1.7 kg (3.7 lb) of lean body mass. Another group lost 0.9 kg (2 lb) of fat while gaining 1.4 kg (3.1 lb) of muscle. In other words, both groups gained lean body mass ('muscle', as people generally use the term in this context) faster than they lost fat. And these were elderly individuals.

Losing fat in a surplus

Based on the above, you can even lose fat in energy surplus. Fat loss occurs during a surplus when you gain muscle fast enough to offset the energy your body receives from the fat loss.

This is easier said than done. You must gain muscle at a rate 5.2 times as high as your rate of fat loss (9441 / 1816 = 5.2). In other words, you must gain 5.2 pounds of muscle for every pound of fat you lose. In an analysis of Menno's client data, this is highly uncommon but possible.

For example, here's the DXA progression report of one of Menno's female clients. The coaching period only started in the last period of this report, so you can ignore the first 2 rows. In the coaching period, she lost 1.3 pounds of fat while gaining 6.8 pounds of lean body mass. That just puts her in positive energy balance during this period by 170 kcal. Here is the full DXA documentation of her progression.

Total Fat Mass Results

Scan Date	Age	Fat Mass (g)	Change/Month vs Baseline	Change/Month vs Previous	Change vs Baseline	Change vs Previous
06/08/2015	34	16021	143	-271	1893	-578
04/03/2015	34	16599	222	373	2471	453
02/24/2015	34	16147	204	204	2018	2018
04/29/2014	33	14128				

Total Lean Mass Results

Scan Date	Age	Lean (g)	Change/Month vs Baseline	Change/Month vs Previous	Change vs Baseline	Change vs Previous
06/08/2015	34	56418.8	313	1451	4157	3098
04/03/2015	34	53320.5	95	-1378	1059	-1675
02/24/2015	34	54995.5	276	276	2734	2734
04/29/2014	33	52261.9				

Gaining fat in a deficit

Following the same logic, you can also gain fat in a deficit. If you lose muscle 5.2 times as fast as you get fat, you gain fat while remaining in a deficit. Unless your weight loss program really sucks though, this should only ever occur if you stop training, you have a serious medical condition or there are drugs involved.

'Maintenance intake'

A commonly advised test to find your energy maintenance intake is to see at which energy intake your weight remains stable for 2 weeks. As you should now understand, this test is fundamentally flawed, as total weight change does not always reflect energy change. It is quite common to see a non-elite individual on a low energy intake not lose any weight or only lose weight very slowly, because they're building muscle at nearly the same rate as they're losing fat. This is excellent progress and mistaking this for a lack of fat loss would mean you put yourself in a highly excessive energy deficit (discussed later).

Adaptive thermogenesis & metabolic damage

When you get leaner, your metabolism decreases faster than you'd predict by the decrease in energy intake (TEF) and loss of body mass (BMR) that occur during dieting. This phenomenon is called adaptive thermogenesis (AT; 'adaptation in heat production'). Many systems in your body coordinate to increase metabolic efficiency as a homeostatic mechanism. This includes downregulation of hormones, notably leptin but also thyroid hormone, and often most importantly, increased movement efficiency in the nervous system and mitochondria, your cells' energy production centers. Many people also experience a decrease in their "appetence for activity" with reduced motivation to move. We effectively become lazier when we're in energy deficit, especially at very low body fat levels. This results in a substantial decrease in spontaneous physical activity (SPA) and non-exercise activity thermogenesis (NEAT) in general. The 'sluggish' feeling very lean individuals have corresponds with reduced movement. They may fidget less, bob their head less when listening to music and in general move more purposefully. Even given the same movements, leaner individuals will expend less energy than fatter individuals, because the metabolic and neural efficiency of the movement increases as well. Adaptive thermogenesis seems to correlate with appetite changes as well, causing increased appetite after fat loss.

These anti-fat loss mechanisms are often called anti-starvation mechanisms. However, it's important to realize that the exact same mechanisms also work in reverse after fat gain: energy expenditure increases and your appetite decreases. Your body 'resists' both fat loss and fat gain, so it's more accurate to call these mechanisms homeostatic mechanisms than merely anti-starvation mechanisms.

Adaptive thermogenesis is primarily determined by your body fat percentage. You can thus think of adaptive thermogenesis as a multiplier that is applied over your total energy expenditure based on your body fat percentage. The multiplier typically ranges between 0.9-1.1, meaning adaptive thermogenesis's contribution to energy expenditure is often no more than 10% of BMR. However, in very lean individuals, such as during contest prep for a bodybuilding show, values of 0.8 have been found compared to 1.2 before, indicating a dramatic decrease of 40% of expected BMR that could not be explained by weight loss during the diet.

Your current energy intake also has an effect on the degree of adaptive thermogenesis, but your body composition is a much stronger determinant of energy expenditure than energy intake. Even long-term overfeeding with a 40% energy surplus increased energy expenditure by only 9% and only 23 kcal of that could not be explained by their increase in fat and lean body mass, according to research by Johanssen et al. (2019).

Adaptive thermogenesis persists as long as you maintain the new body fat percentage, but there is no 'metabolic damage'. The idea of metabolic damage is that adaptive thermogenesis is permanent, regardless of what happens to your body fat percentage after the diet. So the decrease in energy expenditure you suffer from during weight loss is thought to affect future weight loss attempts negatively. This is a myth. Menno's research team's review paper on metabolic damage shows there is no evidence of metabolic damage even in anorectic women, malnourished individuals, the Minnesota Starvation Experiment, bodybuilders during contest prep or wrestlers that aggressively make weight for their competitions. Our metabolism adapts, but even in extreme cases it does not suffer permanent damage.

Your metabolism is determined by your body composition, not your weight loss history. A 2024 review concluded that yo-yo dieting had no persisting negative physiological effects: “The overwhelming majority of evidence suggests that weight-cycling (yo-yo effect) is not associated with any adverse effects in body weight, body composition, and metabolic rate.” A 2018 study found that people that have lost a significant amount of weight on average have the same metabolic rate as same-weight individuals that didn’t lose a lot of weight to get there. Overweight individuals had a higher metabolic rate and this was explained entirely by their body composition, notably their higher weight. Your current metabolism determines your current body composition. Fast weight loss does not decrease your metabolism more than slow weight loss, given the same final body composition change [2] and intermittent energy restriction has the same effect on your metabolism as continuous energy restriction, given the same final body composition change. In other words, our metabolism does not have a history or stopwatch function. It responds only to its acute determinants, notably body composition, physical activity and your diet.

Yo-yo dieting & set point theory

If we don't experience metabolic damage from dieting, why do most people regain most of the weight they lost over time? Some researchers have described this phenomenon as a body fat set point: most people seem to gravitate towards a certain body fat level. This set point is often described as if we have a genetic body fat percentage number printed in us that our bodies will force us back to no matter what we do. However, the reality is that our bodies are governed by physical laws, notably thermodynamics, and there is no evidence we have a genetic body fat set point [2]: weight regain after dieting can be modeled very well based on thermodynamics. What happens is that when we lose fat, we experience metabolic adaptations that facilitate weight regain, namely decreased energy expenditure and increased hunger. If nothing is done to counteract these effects with improved exercise and nutrition, dieting often becomes unsustainable. Put simply, if after your cutting diet you go back to the lifestyle that got you fat in the first place, you'll get fat again.

While BMR is very predictable across individuals, people differ substantially in how adaptive their metabolism is. Someone with an adaptive metabolism tends to experience significant changes in energy expenditure in response to energy intake, cold exposure and protein intake. Some people experience a major decrease in energy expenditure during a fat loss diet, while others have a relatively constant energy expenditure regardless of energy intake. This is why some people need a 2000 Calorie gap in energy intake between cut and bulk phases, whereas others need a gap of only a few hundred Calories.

Intuitively, you may think metabolic downregulation predisposes you to regaining the fat you lost, but metabolic adaptation goes both ways: people with major metabolic slowing during weight loss also experience major metabolic upregulation during weight gain. So an adaptive metabolism doesn't necessarily make it more difficult to stay lean: it theoretically favors weight maintenance. The truth seems to lie somewhere in the middle. In most studies, the degree of metabolic adaptation, whether measured as appetite or energy expenditure, during a diet does not predict the likelihood of weight regain [2, 3 Supporting Information, 4, 5, 6]. However, Pasman et al. (1999) found both hunger and a greater RMR change did predict weight regain and Wang et al. (2008) found that while RMR change did not predict weight regain, a lower physical activity level, which could be due to NEAT, did.

If metabolic adaptations do not consistently predict weight regain, what does? The answer is theoretically very simple: lack of long-term behavior change [2]. When people go 'off their diet', they revert to the same energy intake and overall nutritional and exercise pattern that got them fat in the first place. Precisely because our metabolism is so adaptive and predictable, the same factors that caused them to get fat in the first place will cause them to get just as fat again. In contrast to the inconsistent relation between weight regain and metabolic adaptations, psychological coping with the diet strongly predicts the likelihood of weight regain [2, 3, 4, 5]. To successfully stay lean long term, you have to use sustainable dieting strategies. We'll discuss these in the course module on adherence.

Lack of exercise also makes it much harder to keep off any fat you lost. Muscle loss during dieting increases the likelihood of subsequent weight regain, as it decreases your energy expenditure [2]. Most research subjects don't engage in strength training, so around 25% of weight loss is commonly lean body mass. The resulting decrease in energy expenditure can take a long time to rebuild without strength training, especially when protein intake also isn't optimized. Frequent dieting can then result in a chronically deteriorating body composition and metabolic rate. Preserving muscle mass should thus offset much of the metabolic slowing that may predict weight regain and further weaken any inherent relation between metabolic adaptivity and likelihood of weight regain.

Refeeds & diet breaks

While the term refeed was practically unheard of in nutritional sciences for a long time, refeeds have become a popular concept in some bodybuilding circles as a 'legitimate cheat day'. Refeeds generally take the form of a weekly very high carb day or weekend. The proposed mechanism of action of high carbohydrate refeeding centers around leptin. Leptin is a hormone that plays important functions in the regulation of energy balance and your appetite. Generally speaking, more leptin equals greater energy expenditure and less hunger. Unfortunately for us, evolution made leptin a homeostatic hormone. It's secreted by fat cells, so a decrease in body fat stores is normally accompanied with a decrease in leptin levels, which means your energy expenditure goes down and your appetite increases. The theory is that refeeds prevent these metabolic adaptations to fat loss by tricking the brain into believing you're well-nourished without gaining body fat and thereby keeping your metabolism up during an energy deficit.

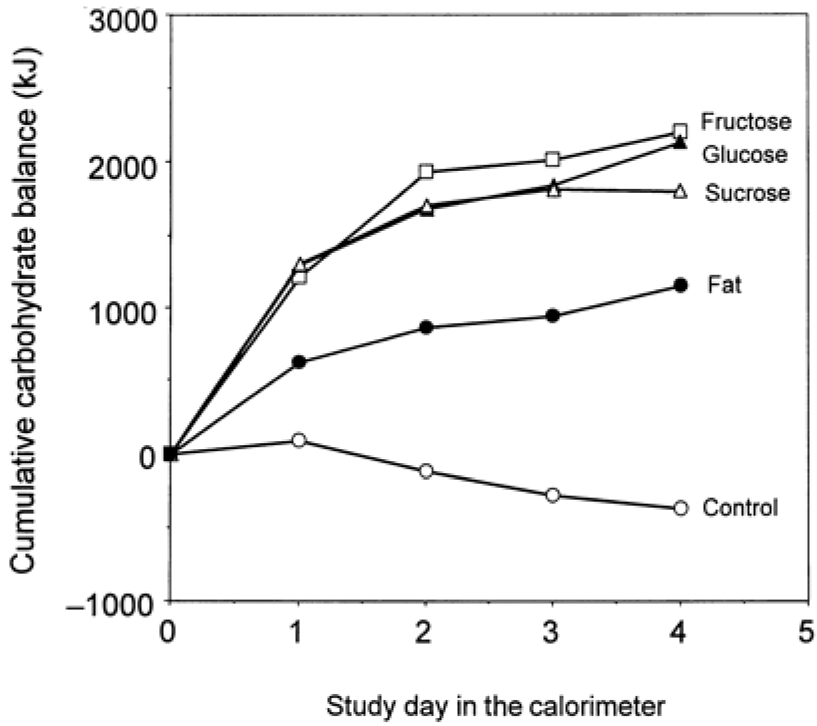
The idea is thus that a refeed majorly ramps up your metabolism and this short kick maintains a higher metabolic rate over subsequent days. However, the effect of even massive overfeeding on energy expenditure is very modest. Dirlewanger et al. (2000) studied the metabolic effects of 3 days of overeating a 40% surplus of energy in the form of a high carb diet. Yes, that's 140% of maintenance energy intake. While there was a moderate 28% increase in leptin levels, this did not correlate with the increase in total daily energy expenditure, which was a paltry 7% or ~140 kcal, leaving the subjects in a 33% net energy surplus to be stored in the body. Basal metabolic rate and physical activity-induced energy expenditure did not significantly increase, indicating that the increase in energy expenditure was due to the thermic effect of the carbohydrate or, at best, a yet unidentified increase in central nervous system-stimulated non-exercise thermogenesis. In short, massive overfeeding accomplished very little for the subjects' metabolism.

Similar findings were reported by McDevitt et al. (2000). 50% overfeeding for 4 days resulted in a modest 7.9% increase in total daily energy expenditure in lean individuals. The increase was the same regardless of whether the overfeeding was on a high-fat or high-carb diet. The type of carbohydrate also didn't affect the increase in energy expenditure. Fructose increased energy expenditure as much as glucose.

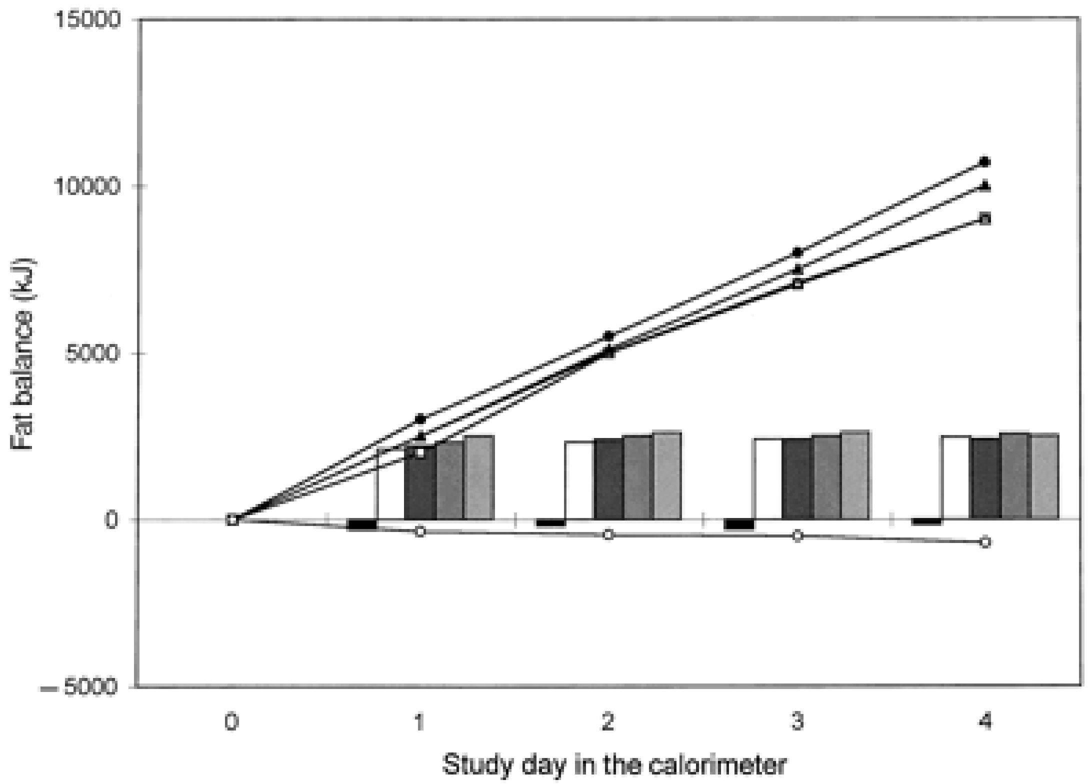
McDevitt et al. also looked at what happened to the excess energy. As expected based on the minor increase in energy expenditure relative to energy intake, much of it was stored.

Protein balance increased by 6-10 g per day, suggesting some muscle growth. Interestingly, protein balance dropped to below zero during the first day of carbohydrate overfeeding before increasing, yet this did not occur during fat overfeeding.

Total carbohydrate balance increased greatly over time: see the graph below. There was no statistically significant difference in glycogen storage between any of the groups, but the carbohydrate overfeeding groups stored ~100 g of glycogen compared to ~70 g of glycogen in the fat overfeeding group. Glycogen storage during fat overfeeding primarily occurs because of a suppression of carbohydrate oxidation and a greater reliance on fat oxidation as fuel.



Total fat balance over time increased similarly in all overfeeding groups with no significant difference between the groups: see the graph below. In other words, the subjects gained a significant amount of fat already from the very first day of overfeeding onward and the increase in fat over time was similar regardless of whether the overfeeding was in the form of a high-carb or high-fat diet.



Daily and cumulative changes in fat balance across all treatments: control (solid bars and open circles), fructose (open bars and open triangles), glucose (striped bars and open squares), sucrose (heavy hatched bars and solid triangles) and fat (light hatched bars and solid circles). The bars represent daily balance; the lines represent cumulative balance.

So refeeding is not a free pass for overeating: you're going to store the vast majority of the excess energy. The next question is: is this worth it for the increase in metabolic rate?

Almost certainly not. There is scant evidence or theory to support that the already small increase in metabolic rate with refeeding persists when you go back to negative energy balance, because the increased energy expenditure is in large part simply due to the thermic effect of your large food consumption, not an increase in basal metabolic rate. When you stop consuming more food, you lose the increase in dietary-induced thermogenesis.

In support of the theory that refeeds don't achieve any permanent increase in energy expenditure, Wing & Jeffery (2003) and Arguin et al. (2013) found that diets with constant daily energy restriction achieve the same body composition change as diets with intermittent energy restriction in the form of diet breaks, given the same total cumulative energy restriction. Arguin et al. also found that resting metabolic rate changes did not differ between groups.

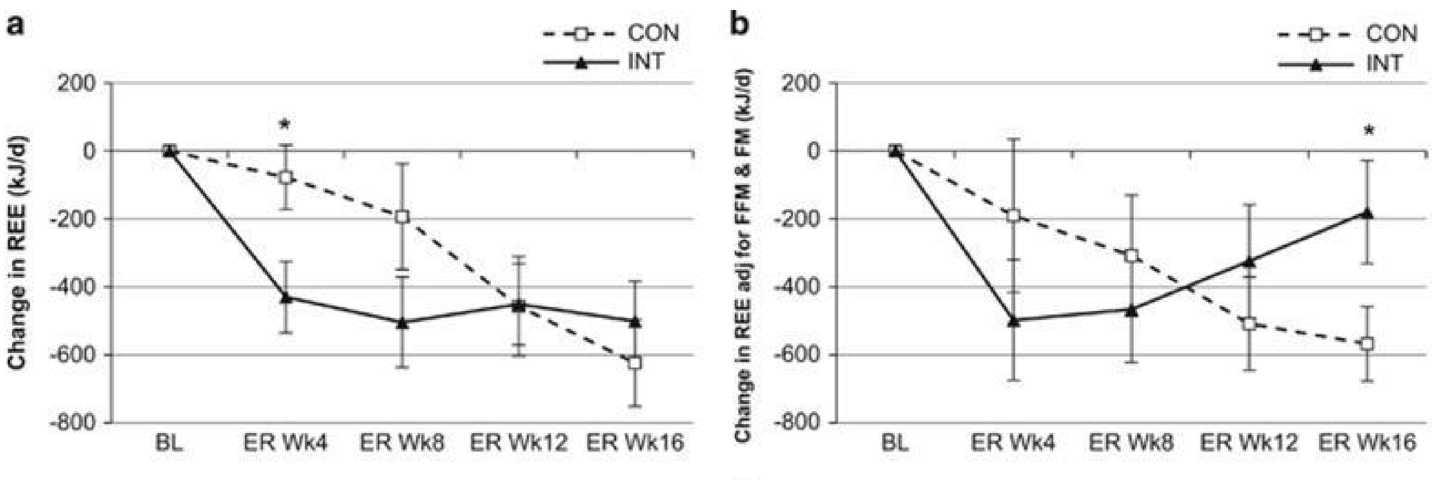
Campbell et al. (2020), corrected by Peos et al. (2020), studied strength trainees on a constant energy deficit compared to an isocaloric diet with weekend carb-up refeeds. There was no difference between groups in the program's effect on their metabolic rate, total training volume, fat loss or fat-free mass. The refeed group did show a higher dry fat-free mass at the end of the study, but this was likely glycogen storage, as they conducted the measurements shortly after the last refeed, which greatly biased their bio-electrical impedance body composition measurement.

In contrast, Davoodi et al. (2014) is sometimes cited to support the ability of refeed days to maintain a higher BMR while dieting, but this study was confounded by a protein intake of 0.94 g/kg (0.4 g/lb) per day in the calorie shifting 'refeed' group compared to 0.78 g/kg (0.3 g/lb) per day in the constant daily energy restriction group. Plus, diet adherence was poor as usual and the weight loss achieved by either group was not what it should have been in obese individuals in a supposedly 45% energy deficit.

The closest evidence to support refeeds, or rather diet breaks, is the MATADOR study by Byrne et al. (2018). These researchers compared 16 weeks of cutting in one go or with a 2-week diet break at maintenance energy intake every 2 weeks with the same planned total energy deficit across the study. At the end of the weight loss diets, there was no significant difference in the resting energy expenditure (REE) change between groups, suggesting the diet breaks were ineffective to maintain a higher metabolic rate, just like in Arguin et al's study.

However, the diet break group lost significantly more fat, mostly because the constant diet group seemed to fall off the wagon after week 12 and no longer lost a significant amount of fat thereafter, whereas the diet break group could stick to their diet longer. (The effect of diet breaks on adherence will be discussed in its own course module.) When corrected for this difference in body composition change, the diet break group maintained a higher REE. The statistical magic to compute REE here is very contentious for several reasons.

- First, the authors did not report which formula they used for the adjustment.
- Second, the diet break group had a lower REE at the start of the study, so a smaller decrease may be expected.
- Third, no mechanism was reported by which the diet breaks could maintain a higher REE.
- Fourth, the pattern over time was inconsistent. As you can see in the graphs below, REE was actually higher in the constant diet group than in the diet break group after the first 4 weeks of energy restriction (figure A). The diet break group had a very peculiar decrease pattern with a miraculous increase in adjusted REE over the course of the study, which should be impossible due to adaptive thermogenesis, which caused a significant between-group difference only at week 16 and only for the adjusted REE.



Given the contentiousness and implausibility of the calculated REE data after adjustment for body composition change, more weight should arguably be given to the actually measured REE values. Measured REE did not differ between groups, suggesting the diet breaks did not help maintain a higher metabolic rate, in line with an abundance of data showing that only the total amount, not the pattern of energy restriction, affects body composition change and metabolism in sedentary individuals [2, 3].

A more tightly-controlled study on diet breaks in strength trainees by Peos et al. (2021) also found no effect of the diet breaks on the participants' metabolism. The trainees performed the same fat loss diet program either in one 12-week stretch or as 4 3-week stretches with 1-week diet breaks in between with maintenance energy intake. At the end of the study, there were no differences in any measures of the participants' metabolism, body composition or physical performance. The lack of diet breaks' effect on RMR or body recomposition was replicated in a very similar study by Siedler et al. (2023), co-authored by Menno Henselmans, in strength training women.

Moura et al. (2021) also found strong evidence that carbohydrate refeeds don't increase subsequent training performance: directly after a large carbohydrate refeed following a cutting phase, a group of trained bodybuilders couldn't complete more reps in a German Volume Training workout (10 sets to failure at 70% of 1RM) than before in energy deficit.

In terms of appetite, in contrast to popular belief (wishful thinking), your appetite also does not generally decrease considerably in the days after short-term refeeding. Human appetite regulation is primarily driven by body composition, not energy intake, so how many calories you eat on one day does not normally influence how much hunger you have in the subsequent days [2]. In some research 60% overfeeding *increases* rather than decreases appetite. The higher appetite after overeating was probably psychological: once you get into the mindset and habit of eating more (not to say binging), it can be hard to stop. Longer-term refeeding can help reduce appetite more effectively. The aforementioned diet break study by Peos et al. (2021) found a reduction in average appetite in the diet break group. However, this came at the cost of spending 25% more time on the diet, so it's likely that they would have gotten better results by dieting at a slightly lower energy deficit than with the refeed weeks.

As for leptin, in so far as the increase in leptin levels is practically significant in the first place, leptin levels in response to energy balance adapt quickly, within 12 hours [2]. Moreover, since leptin is produced by your fat cells, it shouldn't be surprising that leptin levels are very strongly correlated to your total fat mass, not your acute energy balance. As such, leptin levels correspond with *cumulative*, not acute, energy balance, and to increase your leptin levels back to pre-weight loss values, you have to restore the whole diet period's energy deficit and thus essentially gain back all the fat, or at least stored energy, you lost. It is not enough to restore energy balance: you must repay your whole energy debt. Unsurprisingly then, Peos et al. (2021) found no effects of diet breaks on leptin levels.

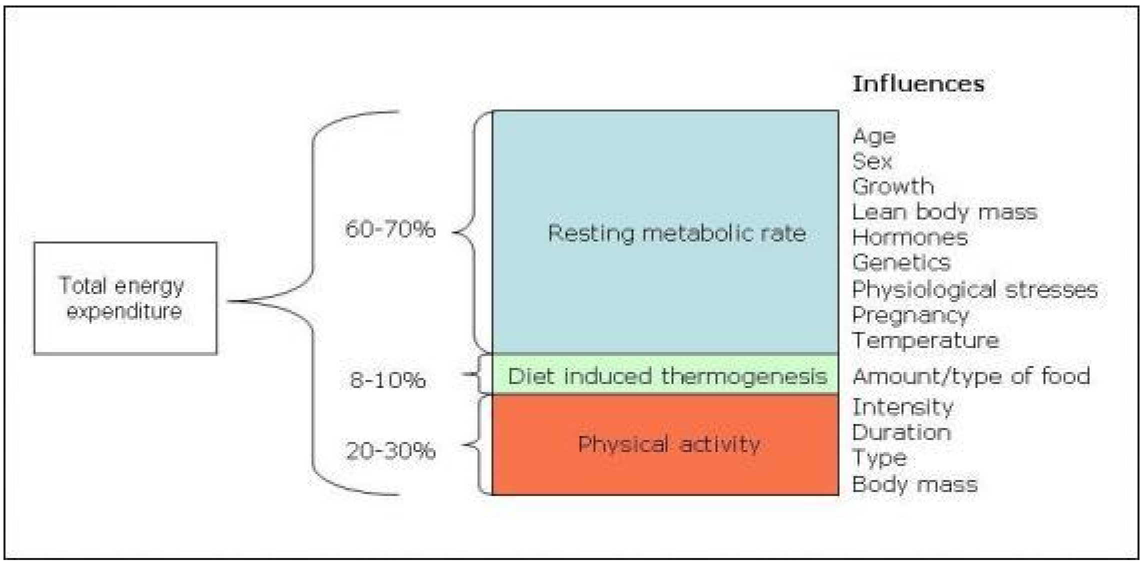
In conclusion, you cannot trick your metabolism into believing you're at a higher body fat percentage or in more positive energy balance than you are. The increase in energy expenditure during even massive carbohydrate overfeeding is only a few percent and leptin levels respond not mainly to acute energy balance but rather to cumulative energy balance over time and total fat mass. As such, in the best-case scenario a refeed often results in pausing your fat loss. Major overeating one day of the week can easily undo the entire week's worth of fat loss efforts or even result in net fat gain across the week, so beware of rationalizing cheats meals as 'refeeds'. Given the same total weekly energy intake, the distribution of this intake does not affect fat loss under most circumstances.

Note: We'll discuss the psychology of refeeds and cheat meals in the course topic on compliance.

Estimating energy expenditure

Now that you understand what energy is and how thermodynamics work, we can go into how to estimate your energy expenditure.

Your metabolism is the sum of various components that together make up your total daily energy expenditure, as illustrated below (data from non-strength trainees).



Basal metabolic rate

The core of your metabolism is your resting metabolic rate (RMR), also called basal metabolic rate (BMR) and often measured in practice as your sleeping metabolic rate. It is the energy your body expends when completely sedentary and fasted, the amount of energy required to sustain your body's primary functions. Theoretically, RMR and sleeping metabolic rate are not the same as true basal metabolic rate, but measuring true BMR requires being fasted and sedentary for a prolonged period, which is of course problematic in research. Sometimes resting energy expenditure (REE) is also used to refer to BMR, but this is not always appropriate, because under normal circumstances resting does not entail fasting. So REE should include not just the resting metabolic rate but also the thermic effect of food.

The most validated formula we have to estimate basal metabolic rate (BMR) is Cunningham (1991)'s formula. It's a finetuning of Cunningham's original 1980 formula, which tended to overestimate BMR, and it's been validated in a wide range of populations from untrained individuals to athletes. Cunningham (1991)'s formula is also known as the Katch-McArdle formula, as they popularized its use. It's also the formula used by most InBody machines. The formula estimates BMR in kcal from fat-free mass (FFM) in kg. For example, the formula estimates that an individual with 70 kg of FFM has a BMR of 370 + 21.6 × 70 = 1882 kcal.

$$\text{Cunningham (1991) BMR} = 370 + 21.6 \times \text{FFM}$$

The Cunningham (1991) formula is superior to the more common formulas, especially in strength trainees [2, 3, 4, 5, 6, 7], because it is based on FFM instead of total bodyweight. Since BMR is primarily a function of LBM and fat mass has very little additional effect on BMR, most bodyweight based formulas, like Harris-Benedict, considerably underestimate BMR in athletes and individuals with above average muscle mass [2, 3, 4, 5]. The Harris-Benedict formula also estimates BMR differently for men and women, whereas in reality the relationship between body composition and BMR is the same in men and women [2, 3, 4]. A theoretically sound formula of BMR should only base its estimates on causative factors of BMR, not sex, height or age.

If you really have no idea what your body fat percentage is but you have an athletic body composition, you can use the Ten Haaf et al. (2014) formula below [2, 3]. It's reasonably accurate specifically for athletes according to multiple studies. However, we recommend only using it when you have no reasonable estimate of your body fat percentage, as the formula is clearly overfitted to non-causative correlates of BMR: height, age and sex. You'll get a calculator later in the module to do the math for you, so don't worry about the complexity of the formula.

$$\mathrm{REE(kJ/d)} = 49.940^{*}\,weight(kg) + 2459.053^{*}\,height(m) - 34.014^{*}\,age(y) + 799.257^{*}\,sex(\mathrm{M}=1,\mathrm{F}=0) + 122.502$$

For physique athletes specifically, the Tinsley et al. (2018) formula shown below is highly accurate [2, 3]. It's even more accurate than the Cunningham (1991) formula in bodybuilders on androgenic-anabolic steroids. It's also incredibly simple. However, its simplistic use of nothing but bodyweight means it's only accurate for highly muscular and lean individuals, such as physique competitors and high-level athletes.

Tinsley et al. (2018) RMR = 24.8 × BW (kg) + 10

In short, you generally want to use the Cunningham (1991) formula to estimate your BMR, but if you're very muscular and lean, the Tinsley et al. (2018) formula is better. If you're fit and have no reasonable estimate of your body fat percentage, you can use the Ten Haaf et al. (2014) formula to estimate your BMR.

Technical note: FFM vs LBM

Note that the Cunningham (1991) formula is based on FFM, not lean body mass (LBM). The terms are often used interchangeably in practice and even Cunningham referred to LBM in the original formula, but they are theoretically not the same. FFM is a simple chemical distinction of lipid vs. non-lipid tissue, whereas LBM is an anatomical distinction of adipose vs. non-adipose tissue.

- FFM = bodyweight minus all lipid mass = BW × (1 – BF%/100)
  Example: A 100 kg person with 10% body fat has 100 × (1 – 10/100) = 90 kg FFM
- LBM = bodyweight minus all adipose tissue mass

FFM is a very simple mathematical measure of total bodyweight without all the lipid mass in your body, essential or not. LBM is more of a theoretical construct. LBM is bodyweight minus all the non-essential adipose tissue below your skin (subcutaneous fat) and around your organs (visceral fat). LBM differs from FFM in 2 ways:

- LBM counts the water in adipose tissue as fat mass: LBM basically looks at all your fat tissue as fat, even though technically there is water and a bit of other lean tissue in adipose tissue.
- LBM counts essential fat as lean body mass, so the fat in your organ membranes, spinal cord, muscle cells, bone marrow and brain are considered lean mass.

In practice, all calculations use FFM though we are really concerned with LBM, since losing water from your fat stores is cosmetically desirable just like the loss of the actual lipid mass. Technically, however, that is FFM loss. Whereas LBM and FFM differ by a few percent in absolute values, *changes* in FFM and LBM correlate extremely strongly to the point they are functionally often interchangeable.

Estimating body fat percentage

To calculate your FFM, you need to know your body fat percentage (BF%). Scientists use various types of laboratory equipment to estimate someone's body fat percentage. If you have such data available, like a recent fasted DXA scan, they generally provide the best estimate of your body fat percentage you'll get. We'll discuss the various types of equipment and their accuracy in the section on body composition tracking later. If you don't have such data available, there are still several other tools to estimate your BF%.

BMI

The most common method of body composition measurement in the general population is body mass index (BMI), dating back all the way to the 1860s (then called Quetelet's Index). The higher your BMI, the heavier you are relative to your height. In *untrained* individuals, weight and body fat percentage correlate reasonably well under normal circumstances.

$$\text{Body mass index} = \frac{\text{Weight}}{\text{Height}^2}$$

Here's a calculator to do the BMI math for you. You can also use the chart below.

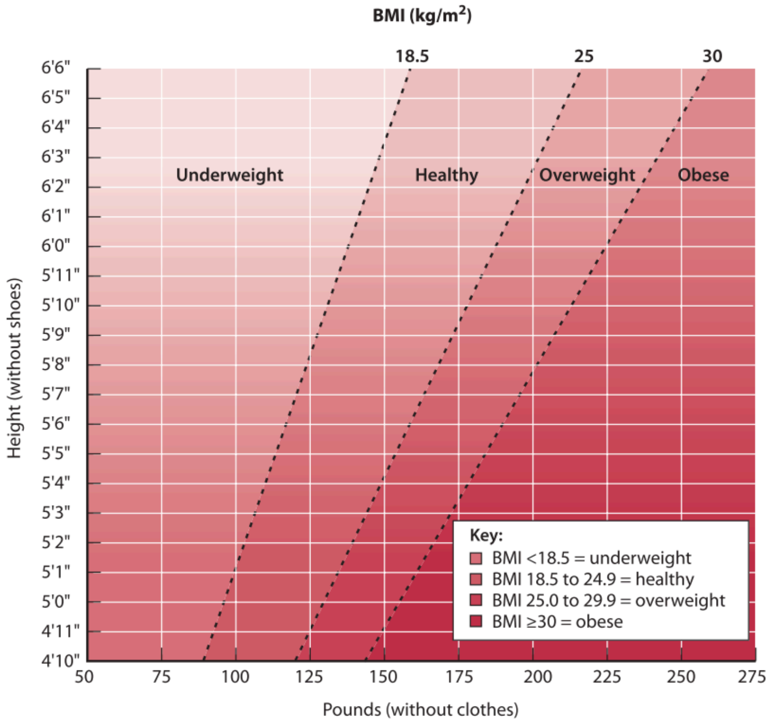


Figure 8.1 BMI values used to assess weight.
Source: U.S. Department of Agriculture and Human Services, Nutrition and Your Health: Dietary Guidelines for Americans. Washington, DC, 2000, p. 7.

Body fat classification based on BMI.

Note that BMI does not actually measure or even predict body fat percentage. It only relates weight in kilograms (kg) to height in meters (m) with the following calculation. However, with the assumption of a certain level of lean body mass based on the person's biological sex and age, this allows us to calculate body fat percentage (BF%) with the Deurenberg et al. (1991) formula. For example, an untrained, 40-years-old woman with a BMI of 30 has an estimated BF% of 1.20 × 30 + 0.23 × 40 - 10.8 × 0 - 5.4 = 39.8%.

Deurenberg et al. (1991) BF% = 1.20 × BMI + 0.23 × *age* - 10.8 × *sex* - 5.4

(sex = 0 for women; 1 for men)

Estimating body fat percentage like this works well for untrained individuals. However, exercising individuals obviously have a greater amount of lean body mass than sedentary individuals at any given bodyweight, and as such, the use of BMI will greatly overestimate their body fat percentage. For example, at 185 cm (6.1 ft) and 90 kg (198.4 lb) with abs, Menno is overweight according to his BMI. A powerlifting friend of Menno had an increase in his health insurance policy payments, because according to his BMI he was obese. He framed that notice letter on his wall.

BMI is now well recognized to be a poor tool to measure the body fat percentage of strength training individuals. What is less known is that BMI can also *underestimate* body fat percentage in sedentary individuals. In our current society, because of near-zero activity levels and poor nutrition, many clinically overweight individuals have a normal BMI because they have so little muscle mass. Scientists call this sarcopenic obesity. Most people call it 'skinny fat'.

The Deurenberg et al. formula is thus generally not useful for trained individuals, but its research does provide us with a useful rule of thumb to equate body fat levels between the genders. Based on its data, women have a 10.8% higher body fat level than men. So a man with 10% body fat looks about as lean as a woman with 20.8% body fat.

Visual estimation

As we will discuss in the section on progression measurement later on, most people are terrible at visually estimating someone's body fat percentage. A particularly important reason is all these images you see online with a set of photos with listed body fat percentages. Looking at these images is one of the absolute worst things you can do to become good at visually estimating your body fat percentage, because you'll often engrain wrong relations between visual appearance and body fat percentage. These collages are generally created by someone who just plucked together a couple of photos from the internet and slapped on some numbers that he or she thought were good estimates. This creates a vicious circle on the internet where the truth goes increasingly lost, while confidence of everyone in their ability to determine someone's body composition based on a photo keeps increasing.

To help you master the skill of visually estimating body fat percentage, here's an evidence-based reference guide. All the photos in this guide were made within a few days of having done a reliable 2C or better body composition measurement. For women, it can be useful to know that your body fat percentage will be about 10% higher than that of men at a comparable level of visual leanness due to higher essential body fat stores and breast tissue.

➢ PT Toolkit

Body fat percentage visual reference guide

Skinfold calipers

Skinfold calipers are one of the most practical tools to estimate your body fat percentage. They are relatively cheap, portable and quite accurate in the hands of a proficient user. If you have good calipers (we'll discuss good brands in detail later), you can use Menno's body fat percentage calculator to estimate your body fat percentage based on skinfold thicknesses. The estimate of this calculator is generally at least within a few percent of the true body fat percentage. Anecdotally, the calculator slightly underestimates body fat percentages in muscular individuals, meaning advanced trainees are typically a bit fatter in reality than what the calculator estimates.

➢ PT Toolkit

Caliper body fat percentage calculator

Setting activity level

To go from resting energy expenditure to total daily energy expenditure, you need to multiply your resting energy expenditure with a physical activity multiplier. This multiplier is known as a Physical Activity Level (PAL) value. On a non-training day, REE × PAL = TDEE. You could in theory also calculate the energy expenditure of all of your daily activities, but that's a huge hassle and it's unlikely to be more accurate in the end due to the all the required assumptions and estimates.

Based on extensive experimentation in his PT Client Application Form with several activity level questionnaires, Menno has settled on the following question to estimate a person's activity level.

Activity level

Please mark one of the fields below or delete the rest.

- Sedentary (e.g. office job with standard life chores)
- Somewhat active (e.g. part-time PT or long daily commute by bicycle)
- Active (e.g. full-time PT, literally on your feet most of the day)
- Very active (e.g. involved in manual labor)

These values translate into activity multipliers as follows.

	PA Values for Different Physical Activity Levels [65]			
Gender	Sedentary	Low active	Active	Very Active
Men	1.00	1.11	1.25	1.48
Women	1.00	1.12	1.27	1.45

Source: Advanced Nutrition and Human Metabolism, 6th ed., closely supported by Gerrior et al. (2006)

Note that 'sedentary' covers standard life chores. Walking your dog, doing groceries and daily chores are not enough to move up to the 'lightly active' category. You generally need some form of prolonged or intensive physical activity to not be considered sedentary for the purpose of your PAL.

Many people tend to overestimate their physical activity level because they confuse stress ('mental activity') with physical activity. Even if you were mentally occupied the whole day, if you were sitting during the period, your activity level was still sedentary. There is only a moderate correlation of 0.37 between people's self-reported activity level and their objectively measured activity level [2]. Specifically, 60% of people overestimate their physical activity level. Women and overweight individuals tend to overestimate their physical activity level most [2, 3, 4], whereas lean men don't have a clear bias.

When in any doubt, round down the activity factor significantly. In fact, in practice it's not a bad rule of thumb to think of your activity level as the maximum of your possible estimate.

Strength training

The energy expenditure from strength training should be calculated separately for maximum accuracy, not factored in to the total physical activity level. Combining them gives a very crude estimate of energy expenditure, because PAL values are not calibrated for strength trainees. During strength training, energy expenditure is approximately 0.1 kcal/kg/min in trained individuals performing intense workouts [2, 3]. This generally corresponds with 300-500 kcal per intensive workout [2]. For example, an 80 kg individual intensely training for 60 minutes burns approximately 0.1 × 80 × 60 = 480 kcal during the workout. Submaximal training sessions may burn as few as 2 kcal/min.

The exercise intensity (%1RM, not to be confused with intensiveness) does not considerably influence energy expenditure, given maximal training effort [2, 3, 4]: higher rep sets can require more energy, but higher intensity sets typically produce a greater 'afterburn', formally excess post-exercise energy expenditure (EPOC). EPOC is the result of tissues catching up on their oxygen debt and replenishing their ATP and creatine-phosphate stores, after which resting metabolism stays mildly elevated due to an elevated core body temperature and other elevated metabolic activity to recover from the workout. Since the intensity of exercise doesn't affect energy expenditure, you don't have to bother with counting reps and you can simply go by the total time spent exercising.

However, when estimating the time a workout takes, be conservative and use the time you could perform the workout in if you pushed through efficiently and intensely. Checking Instagram on your phone in between sets obviously doesn't burn much energy. A reasonable rule of thumb is to count 2.5 minutes per work set in the workout, so a workout with 20 hard sets can be counted as a 20 × 2.5 = 50-minute workout. That would simplify the resistance training workout energy expenditure in kcal (RTEE) to: RTEE = 0.25 × *bodyweight in kg* × *number of sets*

On a technical note, the 0.1 kcal/kg/min figure is not the above basal estimate: it's not the net energy expenditure compared to rest. It's the total energy expenditure of the workout, but you'd also have spent energy doing something else, so you theoretically have to subtract this basal energy expenditure from your workout energy expenditure to get the above basal *increase* in energy expenditure. However, you can treat the workout's energy expenditure as above basal for the sake of simplicity, as the workout also causes EPOC and we can assume the EPOC roughly cancels out the basal energy expenditure. That said, the EPOC of most workouts only amounts to an energy expenditure of about 50 kcal, so be conservative with estimating strength training energy expenditure. If your general daily physical activity level is high, you may want to reduce the energy expenditure by your basal or rest day energy expenditure. For a one-hour workout, that means you subtract REE / 24. Then RT EE in kcal = 0.1 × *bodyweight in kg* × *minutes of workout* - REE / 24. Which is equal to:
RTEE = 6 × *workout duration in hours* × *bodyweight in kg* - REE / 24
(We'll discuss estimates for the energy expenditure of cardio in the cardio course module.)

In sum, to convert resting energy expenditure to total energy expenditure, you multiply REE with PAL. On training days, you should add the energy expenditure of the workout separately. The simplest estimate of a workout's energy expenditure is:
RTEE = 0.25 × *bodyweight in kg* × *number of sets*

Activity trackers

An alternative method to set your activity level is by using an accelerometer, usually a wrist or hip worn device like the FitBit that tracks your movements. Depending on which study you look at, some of these activity trackers, namely the FitBit and the Jawbone, are reasonably reliable at measuring your activity level. Activity trackers are not as accurate as laboratory grade actigraphy or accelerometry, but they correlate moderately to strongly with it with relatively little bias [2]. Problematically though, the bias is not very large, often below 20%, but it's systematic.

Phone apps offer an even less costly and more convenient way to track your activity level than the accelerometer gadgets. The iPhone SE app comes reasonably close to the accuracy of the ActiGraph trackers and the Garmin Vivofit 2 wristband when it comes to tracking step counts under simple conditions, but the Samsung Galaxy S6 Edge is less reliable.

While activity trackers do a decent job estimating activity level, they perform far worse at estimating actual energy expenditure. Virtually all commercially available activity tracker estimates poorly correlate with actual energy expenditure [2, 3, 4], as measured by gold-standard technology (doubly-labeled water or a metabolic chamber): see the following tables for an overview of estimated vs. actual energy expenditure of many activity trackers. In the relatively simple context of a day in a metabolic chamber, physical activity energy expenditure estimates from 12 activity trackers ranged from 24 kcal to 776 kcal, compared to the metabolic chamber estimate of 528 kcal. Across 15 free-living days, the activity tracker estimates ranged from 0.2 kcal to 716 kcal, compared to the doubly-labeled water estimate of 728 kcal: only 2 out of the 12 activity trackers provided reasonable estimates in this situation.

	A standardized day (Measured by metabolic chamber: 528.8 ± 149.4 kcal/day)			
	Difference in PAEE between each device and metabolic chamber (kcal/day)	Estimated PAEE by each device (kcal/day)	MAPE (%)	Bland-Altman
	-1200 -800 -400 0 400	avg ± SD	avg ± SD	r [a]
Withings Pulse O2		24.4 ± 56.7 [b]	93.7 ± 13.9	-0.94 [c]
Garmin vivofit		29.5 ± 34.0 [b]	92.8 ± 13.1	-0.98 [c]
Misfit Shine		291.3 ± 89.0 [b]	50.5 ± 22.9	-0.86 [c]
EPSON PULSENSE		299.2 ± 144.7 [b]	52.8 ± 34.1	-0.74 [c]
JAWBONE UP24		321.7 ± 63.9 [b]	40.2 ± 16.0	-0.91 [c]
ActiGraph GT3X		423.9 ± 145.9 [b]	32.0 ± 20.6	-0.64 [c]
TANITA AM-160		513.8 ± 135.0	29.9 ± 27.6	-0.62 [c]
SUZUKEN Lifecorder EX		519.3 ± 89.3	26.5 ± 39.3	-0.82 [c]
Panasonic Actimarker		545.9 ± 141.7	31.7 ± 39.5	-0.65 [c]
Fitbit Flex		637.0 ± 115.9 [b]	39.7 ± 54.3	-0.74 [c]
Omron Active style Pro		737.0 ± 154.9 [b]	56.3 ± 55.3	-0.59 [c]
Omron CaloriScan		776.1 ± 138.2 [b]	62.9 ± 63.9	-0.62 [c]

	15 free-living days (Measured by DLW method: 728.0 ± 162.7 kcal/day)			
	Difference in PAEE between each device and DLW method (kcal/day)	Estimated PAEE by each device (kcal/day)	MAPE (%)	Bland-Altman
	-1200 -800 -400 0 400	avg ± SD	avg ± SD	r [a]
Withings Pulse O2		8.0 ± 63.9 [b]	98.4 ± 9.6	-0.94 [c]
Garmin vivofit		0.2 ± 42.9 [b]	100.2 ± 6.3	-0.97 [c]
Misfit Shine		167.7 ± 102.0 [b]	76.7 ± 13.9	-0.80 [c]
EPSON PULSENSE		270.8 ± 147.6 [b]	61.3 ± 21.3	-0.73 [c]
JAWBONE UP24		239.2 ± 91.8 [b]	65.9 ± 13.8	-0.86 [c]
ActiGraph GT3X		306.5 ± 172.5 [b]	57.9 ± 23.4	-0.50 [c]
TANITA AM-160		474.5 ± 179.2 [b]	36.3 ± 19.6	-0.47 [c]
SUZUKEN Lifecorder EX		503.6 ± 122.3 [b]	30.9 ± 16.5	-0.73 [c]
Panasonic Actimarker		535.4 ± 149.7 [b]	29.2 ± 15.3	-0.57 [c]
Fitbit Flex		567.8 ± 163.6 [b]	27.8 ± 15.9	-0.58 [c]
Omron Active style Pro		716.2 ± 159.0	19.4 ± 14.9	-0.53 [c]
Omron CaloriScan		707.5 ± 172.7	19.4 ± 15.2	-0.50 [c]

Energy expenditure of consumer grade activity trackers vs. laboratory grade measurements. [Source]

The fundamental problem with activity trackers is that they just register rough movement, not actual energy expenditure – and research in lean, muscular individuals is lacking.

Still, in terms of precision they are arguably better than guesstimating your activity level. The following table based on Locke & Bassett (2004) and Althoff et al. (2017) can be used to translate average daily step counts to an activity level. Be conservative with the 'active' and especially the 'highly active' categories, as these typically have to involve more strenuous movement than just regular walking to warrant activity multipliers of 1.25 and above. As we'll discuss in the module on cardio, high activity levels may also suffer from adaptive thermogenesis.

Activity level	Step count
Sedentary	below 7,500
Somewhat active	7,500 – 9,999
Active	10,000 – 12,500
Highly active	over 12,500 with intensive movement

All in all, should you use an activity tracker? Probably not. For one, there is no reason to constantly monitor your activity level if the activity level doesn't vary majorly across days, because energy expenditure evens out on a weekly basis anyway in most cases and you should adjust energy intake based on body composition changes. Someone with an office job may be a bit more active on days with more meetings or on the weekends, for example, but the difference in energy expenditure across days is often trivial. Activity trackers are generally ineffective as an incentive to promote increases in physical activity [2, 3, 4], so if there is no reason to monitor your activity level, there's no use in wearing an activity tracker.

As a guideline of what constitutes considerable variation in activity level, here are some examples when you may want to change your energy intake on a day-to-day basis based on their activity level.

- Personal trainers who have a lot of in-person clients on some days, causing them to be on their feet most of the day, whereas on other days they are almost entirely sedentary and work from their computer.
- A safety inspector may perform office work on certain days, being sedentary, while having to go out in the field to inspect company buildings on other days, resulting in a high activity level.
- Oil rig workers and road workers only work on certain days or in certain periods and then have a high activity level involving manual labor compared to their normally sedentary lifestyle.

Even then, it is debatable if it's worth wearing an activity tracker every day. The problem with these devices, other than having to purchase and wear them, is that they can easily lead to obsession and reduced wellbeing.

Moreover, as we'll get into in the course topic on compliance, it is not advisable for most individuals to focus on their day-to-day energy intake every day, because it makes meal planning and habit formation difficult. As a result, very few individuals end up using activity trackers successfully in the long term.

TEF

In addition to BMR and physical activity, there is another component of energy expenditure that is often forgotten: the thermic effect of food (TEF). After you eat, your metabolic activity increases to process the food. You can think of the TEF as the proportion of food's energy intake that your body burns to metabolize the food. It is not measured as a fraction but as a multiplier, however: BMR × TEF = REE. The thermic effect of food is also called diet induced thermogenesis (DIT). For example, a 500-kcal meal with a 20% TEF increases your energy expenditure by 500 × 0.2 = 100 kcal.

Many PAL values unintentionally include the TEF, as they assume that BMR = REE, but that's only true if you're fasting. Beware of this when interpreting PAL and BMR/REE values.

Based on a very rough average of the literature, TEF is often assumed to be a constant 10%. However, TEF varies substantially based on how easy it is for the body to harvest energy from the food. Snakes that swallow their prey whole, for example, experience an increase in metabolic rate of 687% after eating.

In humans, the variance in TEF is more modest, but in strength trainees it can rise up to 25% based on body fat percentage, carbohydrate tolerance and food type. That is very significant, so if you want to accurately predict your energy balance, you should estimate TEF based on the following factors.

Body fat percentage and carbohydrate tolerance

The thermic effect of fats is lower in overweight people [2]. The TEF of pure dietary fat is close to zero in overweight individuals, but in lean individuals it can rise all the way to ~15%. In the course topic on refeeds you already saw a study where 50% overfeeding led to a 7.9% increase in energy expenditure regardless of whether the energy came from fat or carbohydrate in lean individuals: only in the overweight individuals did fat not have the same thermic effect as carbohydrate. The decreased thermic effect is linked to lower rates of fat oxidation in overweight individuals. This again goes to show how dysfunctional it is to be overweight and why getting lean should always be a priority before bulking. When you're overweight, the body has tons of energy available in the form of fat, but it refuses to use that fuel (to some extent: of course, the body almost always has some amount of fat oxidation).

The thermic effect of carbohydrate also tends to be lower in people with insulin resistance, as they have more trouble taking up glucose from the blood. However, the thermic effect of carbohydrates can also slightly increase at a higher body fat percentage. Some of the variability appears to be due to differences in study methodology, specifically the measurement technique of the TEF, but it is likely that differences in carbohydrate tolerance are important too. (Discussed in the course topic on carbohydrate tolerance.)

So it's a myth that fats always have a lower thermic effect than carbs: it depends on the person's body fat percentage and carbohydrate tolerance. For lean individuals, there is generally no significant difference: fats and carbs both then have a TEF of ~15%. Under isocaloric and protein-matched conditions, the TEF of high- and low-fat meals is often similar.

Protein's TEF is not greatly affected by a person's level of leanness or carbohydrate tolerance and remains steady at ~20%.

Macronutrient composition

Since the TEF of protein is higher than that of fats and carbs, it is tempting to conclude that the more protein you have in your diet, the higher your diet's TEF. Yet you'd be wrong. A 2013 meta-analysis found no relation between a meal's protein content and its thermic effect. Li et al. (2016) found no difference in dietary induced thermogenesis of diets of 10%, 20% or 30% protein. Protein seems to be more thermogenic than carbs or fats in isolation, but in the context of mixed meals, which is far more relevant in practice, the difference tends to disappear.

The same holds for fats vs. carbs. Whereas fats in isolation tend to have a lower thermic effect than carbohydrates, depending on the type of fat and the population, in research where mixed meals higher or lower in fat are compared, there is generally no significant difference in thermogenesis as a function of the carb:fat ratio of the meals [2, 3, 4].

Mixed meals tend to have a relatively constant TEF that is not simply equal to the weighted sum of the TEF of the meal's macronutrients: it is generally higher. Combining pure fats and pure carbs in a meal results in a higher thermic effect than either in isolation.

In lean individuals, the TEF of a regular mixed meal is around 25%. So mixed meals can have a TEF that's even higher than pure protein. Large, mixed meals also tend to have a higher TEF than the same foods consumed in isolation.

As an illustration of how mixed meals do not behave like macronutrients in isolation, Riggs et al. (2007) compared the thermic effect of 2 isocaloric high protein meals: a high fat and a low-fat variant. Since fats in isolation tend to have a lower thermic effect than carbohydrates, depending on the type of fat and the population you compare at least, you'd expect the high fat meal to have a lower thermic effect. In reality, the high fat meal had a higher thermic effect, though this was only apparent in normal weight individuals. In under- and overweight individuals, there was no difference between the TEF of the 2 meals.

For fats in particular, the type of fat also affects their TEF.

- Unsaturated fatty acids tend to have a higher thermic effect than saturated fatty acids [2, 3, 4], although some of the research found the difference are insignificant in the context of mixed meals in overweight individuals [2].
- Medium-chain triglycerides seem to have a higher thermic effect than most other fats, although again some of the research found the difference to be insignificant in the context of mixed meals in overweight individuals.
- Omega-3 fatty acids can increase the thermic effect of a meal by 51.3%.

Differences in the thermic effect of different fatty acids generally cause only small differences in total daily energy expenditure, but they are not necessarily trivial: in some research the difference in TEF is 3-fold. As a result, MCTs can increase fat loss compared to other fats and monounsaturated fat intake can increase fat loss when replacing saturated fat or polyunsaturated fat at the same caloric intake [3].

Food processing

Moreover, the TEF of mixed meals consisting of processed foods is lower than that of whole foods. Whole-grain bread with cheddar cheese has a TEF of 19.9%, whereas white bread with more processed cheese (you know, the rubbery kind) only has a TEF of 10.7%: a nearly 2-fold difference in energy expenditure for meals with the same macros.

A person eating an IIFYM-style maintenance diet of processed food could thus go into a 9.2% deficit simply by filling his or her macros with less processed foods. Processed foods make it far easier for the body to harvest energy from food. And it's quite ironic the researchers chose bread and cheese in the above study, since both are inherently processed foods. Unfortunately, we don't have research to see how major the differences are for foods where energy harvest may be much harder, like fibrous vegetables.

Meal frequency

Eating 6 meals a day is commonly prescribed to lose fat because you get 6 TEF spikes across the day to 'rev up the metabolic furnace'. Is it effective?

All the way back in 1982, researchers compared the effect of meal frequency on energy expenditure. Participants were fed 2 or 6 meals with the same total macronutrient composition and energy content in a whole-body calorimeter, which is essentially a tightly controlled room that measures all the carbon dioxide produced by the participant and their oxygen consumption. This allows us to calculate precisely their total energy expenditure. The 2 meals resulted in 2 large spikes of energy expenditure compared to 6 smaller spikes in metabolic rate for the 6-meal group. Importantly, total energy expenditure, measured as the area under the curve, was the same in both groups.

All subsequent research has unanimously supported the finding that your meal frequency does not directly impact your metabolic rate: see the literature overview below. How many meals you have in your diet does not affect your energy expenditure, because the thermic effect of food is proportional to energy intake. You can either get 6 small increases during the day or 3 big ones, but the total increase is the same if you're consuming the same meals.

➢ Research overview

Effect of meal frequency on energy expenditure

Salt intake

Somehow, it seems a high salt intake can decrease the thermic effect of food. Regardless of what could explain this, it's probably not very practically relevant. A doubling of salt intake from 6 to 12 grams a day decreased the TEF by only 1.3%. It's arguably not worth worrying about this.

Conclusion

Assuming mixed meal compositions, TEF generally varies from 10 to 25%. You can thus multiply your BMR by 1.1 to 1.25 to estimate your sedentary but non-fasting REE. The low end is for overweight people eating an average diet. The higher end is for lean strength trainees eating a high protein diet with plenty of unsaturated fats or MCTs from whole foods, a high volume of food and lots of fiber. So to set calories accurately, you have to take these factors into account and estimate your TEF.

Based on your BMR, PAL and TEF, you can calculate your total daily energy intake (TDEE). If you don't exercise, TDEE = BMR × PAL × TEF. If they do exercise and we separately add resistance training (RT) energy expenditure, you should also add the TEF over the RT EE, so that

TDEE = REE + (RT EE × TEF)

= (BMR × PA + RT EE) × TEF

Remember that TDEE is equal to maintenance energy intake but not necessarily equal to *weight* maintenance energy intake.

The next question is: how many calories should you consume relative to energy maintenance?

Cutting, bulking and body recomposition

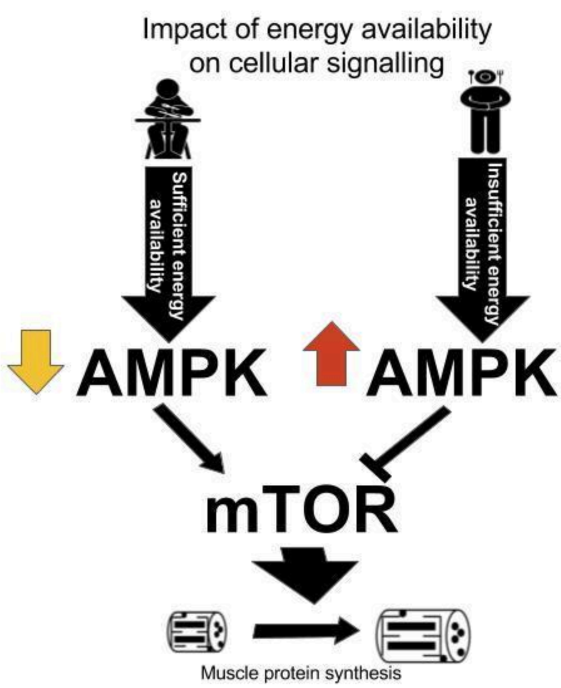
A variety of terms are used to describe how people want to change their physique. Shredded, ripped, lean, slim, bulky, toned, jacked... physiologically, there are only 2 variables to manipulate: fat and muscle mass. Traditionally, bodybuilders picked one variable to work on based on their most important goal and either 'cut' on a fat loss program or 'bulk' on a muscle growth program. This planning is largely based on the false interpretation of energy balance that you need to be in energy surplus to build muscle and in energy deficit to lose fat. As you learned, on a good program you can build muscle and lose fat at the same time.

However, positive body recomposition faces an obstacle for both of the 2 primary ingredients for muscle growth: protein and energy. The availability of protein is a limitation for fat loss. The ideal environment for muscle growth requires hyperaminoacidemia, high levels of amino acids in the blood, for a considerable part of the day. This is a problem for fat loss, since having a lot of amino acids in the blood is not an ideal condition for fat loss. Just ~27 g of whey or soy protein already triggers enough insulin release to suppress fat burning. Of course this is just temporary, but it illustrates that the ideal conditions for fat loss and muscle growth are not the same. On a high energy intake, insulin levels will generally be substantially higher than on a low energy intake and this will limit fat loss. The practical result of this is that trying to lose fat in energy surplus is very difficult. It can happen, as you've seen in some of Menno's clients, but it's rare and normally an inefficient use of time, as you could achieve the same fat loss in a fraction of the time in energy deficit.

Obstacle 2: while your body has plenty of energy available for muscle growth, it may not want to use it for that purpose, because your body has evolved potent anti-starvation mechanisms. Building a lot of muscle mass while dying of famine isn't one of them. To assess what the ideal state of energy balance is for body recomposition, we should look at the effect energy intake has on muscle growth.

Effect of energy intake on muscle growth

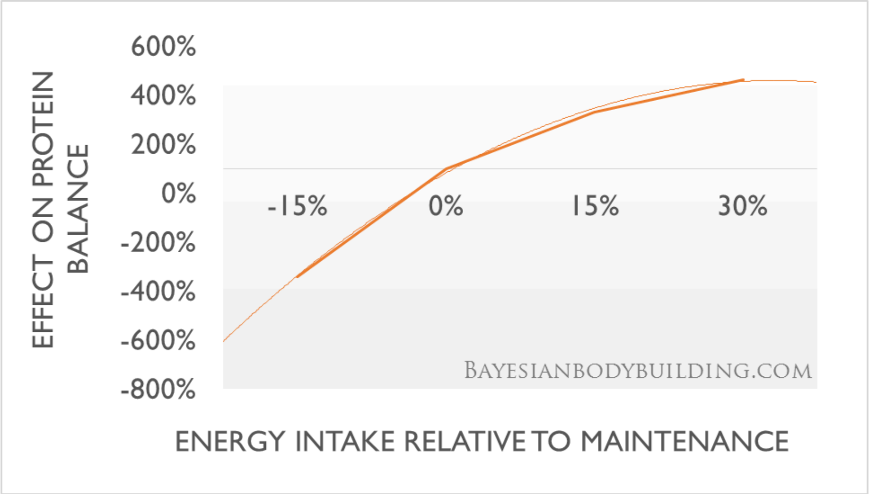
Mechanistically, mTOR and AMPK compete to determine whether a cell undergoes anabolism or catabolism. Anabolism refers to building molecules, whereas catabolism refers to breaking down molecules. mTOR is an enzyme that regulates anabolism, specifically protein synthesis. AMPK is an enzyme that regulates more catabolic processes, particularly fatty acid oxidation and glucose uptake in the muscle to produce energy. Low energy intake activates AMPK and this interferes with mTOR.



Energy availability in a cell influences its rate of protein synthesis. Adapted from [Chaillou et al. (2014)](), [Figueiredo et al. (2015)](), and [Smiles et al. (2016)]().

As a result of the reduced anabolic signaling, muscle protein synthesis (MPS) levels are lower in energy deficit than at energy maintenance or in surplus. Pasiakos et al. (2010) found that protein synthesis and associated intracellular signaling proteins became downregulated after 10 days of 20% energy restriction, despite keeping protein intake at 1.5 g/kg per day. The decrease in protein synthesis was not major though: 19%, which is small relative to changes that occur in response to meals and exercise. Hector et al. (2017) similarly found a 14% decrease in muscle protein synthesis in a whopping 40% energy deficit compared to maintenance energy intake without any change in muscle protein breakdown (MPB). Consuming insufficient protein (1.2 g/kg per day) exacerbated the decrease in MPS anabolism to 26%. Protein breakdown likely only increases in severe energy deficit and after a few days, because it's more efficient for the body to decrease MPS than it is to increase MPB. For example, Larsen et al. (2023) found no effect yet of 5 days of severe energy deficit on myofibrillar protein synthesis in overweight postmenopausal women, not at rest, after a meal or after exercise.

The following graph shows how nitrogen balance changes with energy intake in young men. Nitrogen balance is a whole-body measure, and it's not specific to muscle tissue. Even fat mass consists of up to 7.1% protein. Therefore, these values likely majorly overestimate the impact of energy balance on muscle growth, but they still help illustrate the overall trend of how energy balance affects muscle growth.



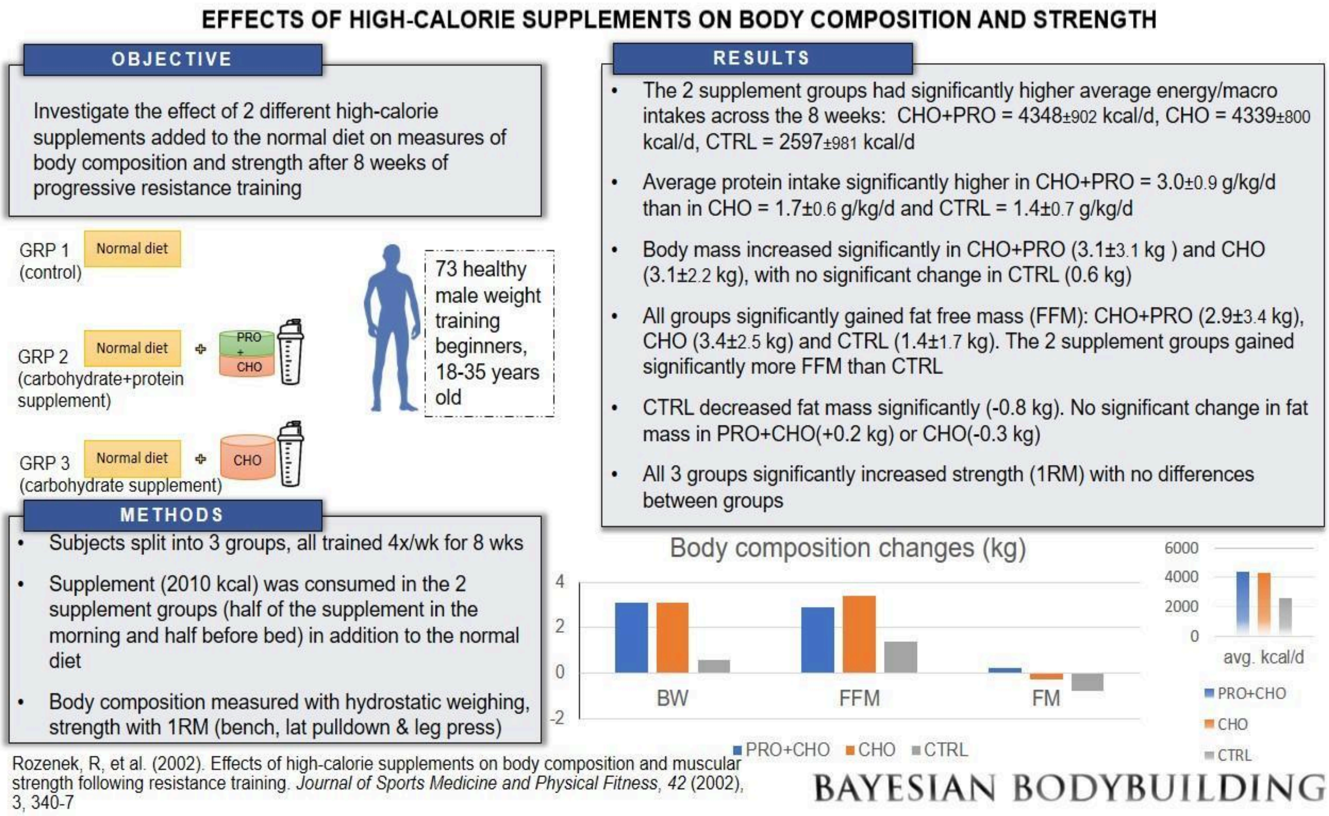
The effect of energy balance on nitrogen balance. Values obtained by integrating and normalizing the data from [Chiang & Huang (1988)] and [Calloway (1975)].

How does the change in protein balance translate into muscle growth? A 2021 meta-analysis by Murphy & Koehler found that energy deficiency moderately impairs resistance training gains in lean mass but not strength. Strength gains are in large part due to neural improvements in the neuromuscular system and our brain. These adaptations are probably not affected much by energy balance, as they're more like software updates than building new hardware. Therefore, you should generally manage to keep gaining strength even when cutting on a good program. However, over the long run the lack of muscle growth should logically impair strength gains, especially in more advanced trainees. Muscle growth on average in the literature became insignificant at an energy deficit of 500 kcal per day. Strength gains may also suffer due to higher fatigue levels when recovery is poorer. We'll discuss the relationship between strength and size in more detail in the course module on understanding muscle growth.

While energy deficiency reliably impairs muscle anabolism, an energy surplus seems to have only minor effects on muscle growth. Multiple studies have looked at the effect of energy intake on muscle growth. (If you're not interested in the study details, you can skip to the Conclusion.)

Rozenek et al. (2002), summarized in the infographic below, compared the effect of adding a 2010 kcal bomb to a control diet in the form of either just carbohydrate or a combination of carbs and protein. Muscle growth was greater in the 2 higher calorie groups than the control group, but the control group was the only group that lost fat. This would suggest a higher energy intake indeed increases muscle growth and a lower energy intake is better for fat loss. However, even this hefty extra energy intake did not influence strength gains significantly. And protein intake was 1.7 vs. 1.4 g/kg (0.8 g vs. 0.6/lb) per day in the carbohydrate group, making it ambiguous if it was the extra protein or energy intake that favorably affected muscle growth. It's entirely possible the extra protein intake resulted in the extra muscle growth and all the extra energy intake did was reduce fat loss.

Hambre et al. (2012) researched the effect of what bodybuilders call 'dirty bulking' in untrained men. The researchers compared supplementing a 12-week strength training program with either 33 g whey or a fast-food meal with 1350 kcal and 41 g protein. The whey group ended up with 1.5 g/kg (0.7 g/lb) of protein per day and 2518 kcal vs. 1.4 g/kg (0.6 g/lb) protein per day and 2982 kcal. In other words: same protein intake, ~500 kcal energy intake difference. Both groups gained 2.1 kg (4.6 lb) of lean body mass, but the fast-food group gained 2 kg (4.4 lb) of fat compared to just 1 kg (2.2 lb) in the whey group. The extra energy intake thus only seemed to increase fat gain without any positive effect on muscle growth.



Garthe et al. (2011) compared 2 groups of elite athletes with a different weight gain rate. While these were elite athletes, in terms of body composition they were still barely intermediates. The study was highly uncontrolled, but we can calculate that during the first 6 months of bulking the weekly average weight gain rates were approximately 0.18% vs. 0.02%. A 0.02% weight gain rate is extremely close to a maintenance diet, so we'll call this the maintenance group. The groups did not differ in their rate of muscle growth or strength in the squat, bench press or bench pull, but the 0.18% group obviously gained more fat than the maintenance group (41% or 4.7 kg / 10.4 lb compared to 3% or 0.4 kg / 0.9 lb).

Garthe et al. (2013) again compared 2 groups of elite athletes with a different weight gain rate: 0.2% (2964 kcal) vs. 0.4% (3585 kcal) bodyweight per week. Again, while these were elite athletes, in terms of strength they were still barely intermediates with a 1RM bench press of ~1.2x bodyweight and a 1RM squat of ~1.7x bodyweight. They performed 4 weekly strength training sessions on top of an average of 16.7 hours of sport specific training. Over 8-12 weeks (9.9 weeks average for both groups), both groups achieved similar gains in muscle mass and performance with no statistically significant differences between groups other than that the 0.4% group gained more fat. See the results below. Note that ALG is the 0.2% group; NCG is the 0.4% group.

Figure 1. Changes in body weight (BW), fat mass (FM), and lean body mass (LBM) in the nutritional counseling group (NCG) and the ad libitum group (ALG). Data are presented as mean±SE.

*p <0.05 significantly different from pre-intervention, **p <0.05 significant difference between groups.

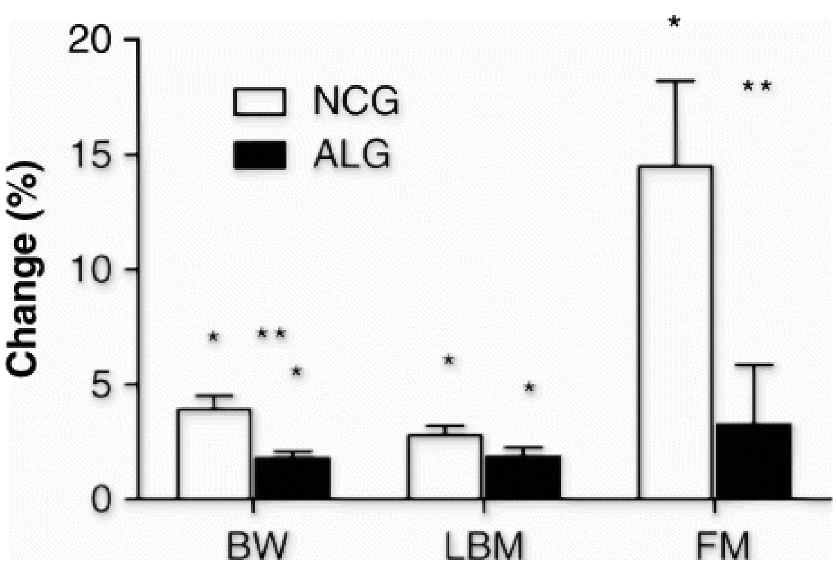
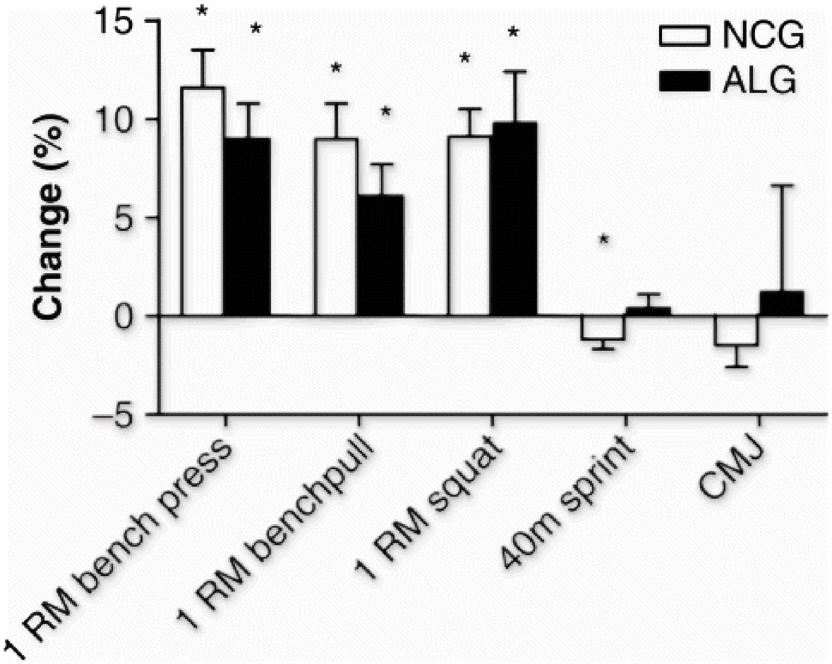
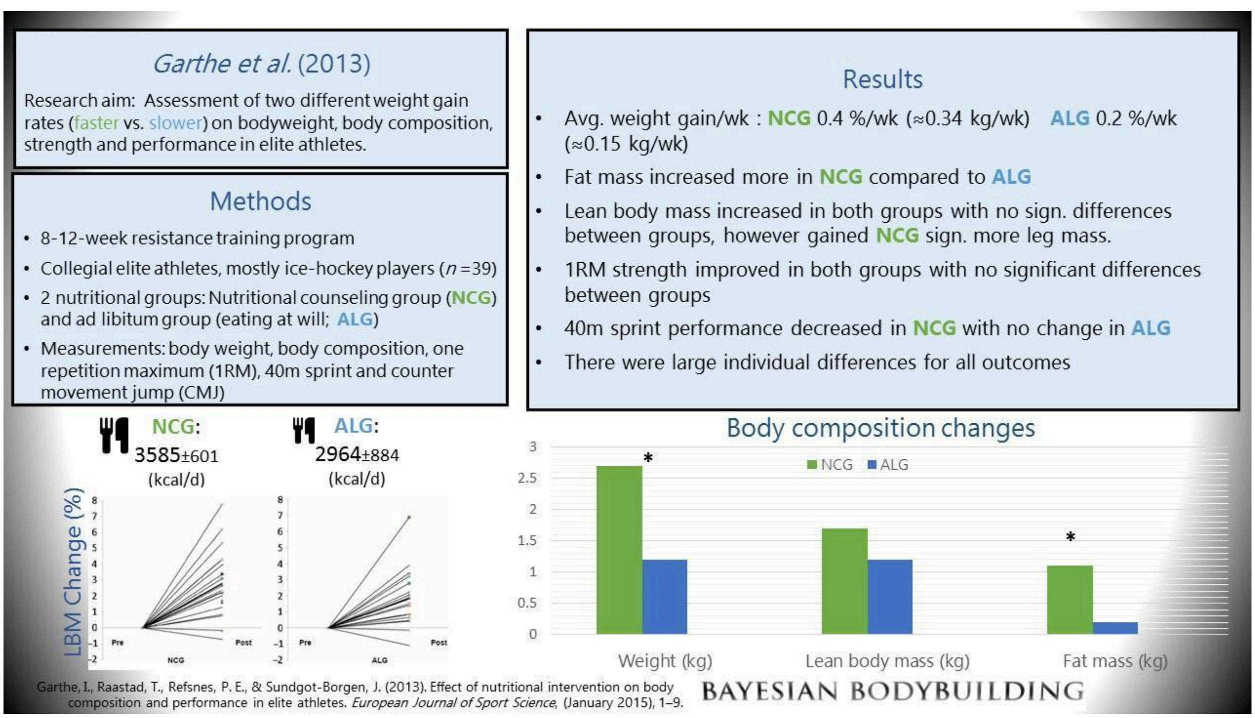


Figure 2. Changes in 1RM bench press, bench pull, squat, counter movement jump (CMJ) and 40 m sprint performance in the nutritional counseling group (NCG) and the ad libitum group (ALG). Data are presented as mean±SE.

*p <0.05 significantly different from pre-intervention.





Compartmental DXA analysis did show that lean body mass in the legs increased by 2.5% in the 0.4% group compared to only 0.2% in the 0.2% group. But the 0.4% group also became significantly slower at the 40 m sprint, indicating that strength relative to bodyweight (relative strength) decreased (and this is far more important for most sports than absolute strength).

The 0.2% group didn't follow a structured meal plan, but since this should only limit their results, this strengthens the finding that a low average weekly rate of weight gain is generally sufficient to come close to maxing out muscle growth.
Interestingly, the 0.2% group had a protein intake of 1.7 g/kg per day compared to 2.4 g/kg per day in the 0.4% group. This shows again that a high protein intake will not save a dreamer-bulk.

Unpublished research from the University of Tampa also found that adding a high dose weight-gainer supplement consisting of ~250 g of carbs to a bulking group's diet resulted in significantly more fat gain but not significantly more muscle growth compared to a more moderate diet.

Ribeiro et al. (2019) found more impressive effects of higher energy intakes. In a 4-week pilot study, Brazilian IFBB bodybuilders bulked on a 429-kcal energy surplus or a 58-kcal energy surplus. Unfortunately, reporting standards were poor and post-intervention fat mass, fat-free mass and even bodyweight weren't reported. Back-calculating their values resulted in different values than the authors reported in private communication with Menno. Going by the percentage changes and assuming that their estimate of muscle mass equals fat-free mass, the energy surpluses must have been 1% vs. 8%. Going by estimated maintenance intake based on this course's guidelines, it would be 15% vs. 2%. If we back-calculate their post-intervention bodyweights, the weekly bodyweight gain rates should have been around 0.5% vs. 1%.

The super-lean bulk group gained 0.1 kg (0.2 lb) fat and 0.4 kg (0.9 lb) muscle. The more aggressive bulk group gained 1.1 kg (2.4 lb) fat and 1 kg (2.2 lb) muscle, over double the muscle growth rate of the super-lean bulk group. These results would support a much higher optimal energy surplus than previous studies.

However, this study was fraught with limitations. Body fat percentage was estimated with skinfolds, muscle mass was estimated with an anthropometric equation instead of measured, energy intake was self-reported, the study only lasted 4 weeks, data reporting was poor and there was no control other than 'I promise' of whether the subjects were on performance enhancing drugs, which Brazilian IFBB bodybuilders are notorious for. As such, not much weight should be given to the exact numbers.
A more general take-home message would be that avoiding all fat gain during a lean bulk is overly conservative. Some of the subjects in the super-lean bulk group experienced a decrease in BF%, indicating they probably weren't even in energy surplus. This alone may have caused the difference in results for the group average: in the more aggressive group, all subjects were in energy surplus compared to only a proportion of the super-lean bulk group. The exact surplus may not have mattered, as previous research would suggest.

A 2023 study by Helms et al. compared maintenance energy intake to a 5% and a 15% energy surplus in trained lifters to see what the optimal energy surplus is for bulking. There was no difference between the groups for muscle growth in any of the 6 measurement sites in the arms and legs, nor for 1RM squat strength. There was an effect on 1RM bench press strength, but this may have been a fluke, because the 5%

energy surplus group somehow had greater gains than the 15% surplus group. However, the participants were likely not adhering to the macros very well, because the 5% surplus group also gained more fat – based on caliper skinfold measures at least – than the 15% surplus group.

Therefore, the authors reran the analysis using bodyweight gain instead of the allocated energy surplus as the predictor. The results were virtually the same. The effect on bench press strength disappeared. While there was a weak effect of weight gain on biceps size, there was still no effect on any of the other 5 measurement sites.
In sum, higher energy surpluses primarily resulted in more fat gain without an appreciable effect on muscle growth or strength gains.

In 2024, Sanchez et al. accidentally studied the effect of energy intake on bulking gains in strength-trained athletes and soldiers. The researchers intended to study the difference between 2 types of calorie-equated snacks on health markers during a lean bulk phase, but the participants didn't adhere to the macros, so one group ended up with a 675 kcal higher average energy intake. This accidentally turned it into a much more interesting study of the effect of energy intake on bulking results. One group had a 3% energy surplus and a 0.2% weekly weight gain rate; the other a 10% surplus with a 0.4% weekly weight gain rate for 10 weeks. Back-calculations of their energy surplus based on their body composition changes aligned well with their self-reported energy intake increases (2% vs 9%). Both groups consumed 1.6 g/kg of protein per day and trained 3x per week with a high training volume. The higher energy surplus group gained significantly more body fat (1.9 vs 0.4 kg), as per DXA scans, but not significantly more lean body mass (1.9 vs 1.3 kg) or 1RM strength on their squats or bench presses (slightly worse gains in the 10% group even). Thus, again we see that higher energy surpluses mainly contribute to fat gain rather than additional gains.

Conclusion

Overall, being in energy deficit impairs muscle growth, but the effect is not major and muscle growth is still possible in energy deficit for many people, especially beginners and people with higher body fat levels. The negative effect of energy deficit is much clearer than the positive effect of energy surplus: while cutting too fast decisively risks muscle loss, bulking too fast speeds up fat gain far more than it speeds up muscle growth. In energy surplus, energy intake seems to have minimal effect on muscle growth and strength development. Beyond a very small energy surplus, most additional energy intake primarily turns into fat gain in natural trainees.

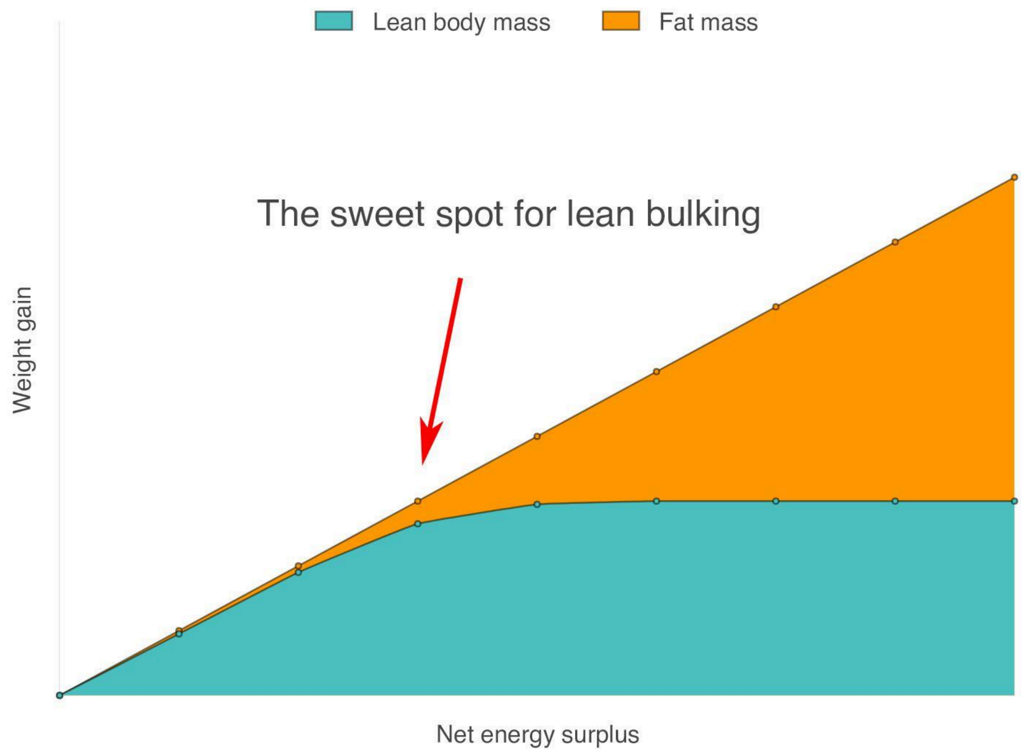
Bulking: practical application

While several aforementioned studies find no effect of the energy surplus on the rate of muscle growth, careful inspection of the data does often show a minor effect, just not statistically significant and far outweighed by the additional fat gain. It seems that the *size* of the energy surplus has almost no effect but there is a positive effect of being in energy surplus vs. being in energy deficit. The sweet spot of energy surplus for a lean bulk is thus very small.

In Menno's experience with his clients, the effect of energy balance on protein balance becomes more relevant at the advanced level. This is in line with the study on Brazilian bodybuilders finding more positive effects than the other studies in less muscular athletes. As it becomes increasingly difficult to signal the body to build further muscle mass, many advanced trainees simply stop gaining *any* appreciable amount of muscle mass while cutting or staying at maintenance. Bulking becomes required for muscle growth and the effect of positive energy balance on strength development is clearly noticeable in many advanced trainees.

The effect of energy intake on muscle growth is also readily observable in androgenic-anabolic steroid using individuals, where muscle growth can be so rapid that all energy surplus will be used to this end and fat gain will be minimal up to absurdly high energy surpluses.

As such, we still want to bulk when someone is lean enough – further cutting is undesirable by definition and maintenance intake is a waste of time – but we don't want to be as aggressive in terms of weight change as when cutting. An exceptional scenario is that of strength athletes in the free weight class that don't care about becoming fat and just need to add as much strength as possible within a certain period, like certain Powerlifters or Olympic weightlifters.



The optimal energy surplus is usually very small for natural trainees. Higher energy surpluses result in significantly more fat gain without much effect on muscular development.

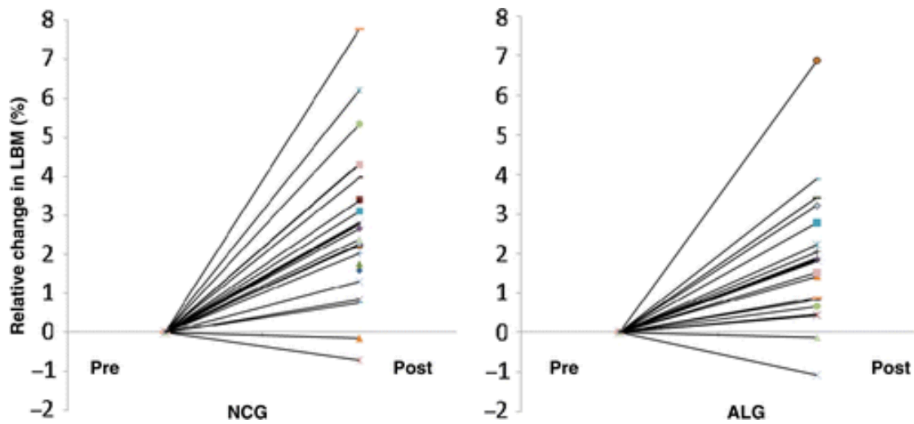
So a different approach to bulking compared to cutting is advisable. Specifically, you should keep pushing calories up as high as they can while only allowing for minimal fat gain AKA lean bulking. Whichever measure of fat gain you're using (e.g. skinfolds, waist circumference, BIA BF%), that measure should barely or not increase during most weeks of a bulk. The following table provides guidelines on the energy surplus to use and the fat-free weight gain rate to target. For example, an 80 kg novice may want to bulk on a 10% energy surplus and should thus multiply their maintenance intake by 1.1

to get their target energy intake, aiming for a weekly weight gain rate of at least 80 × 0.5 / 100 = 0.4 kg (and most likely no more than 0.8 kg).

Training status	Initial energy surplus	Planned weekly weight gain rate (% bodyweight)
Novice	5-15%	0.5-1%
Intermediate	2-7%	0.2-0.5%
Advanced	1-3%	any fat-free

As the bulk progresses, you'll need to update energy intake based on the measured body composition change. It's crucial to go by the observed data rather than any predetermined numbers for 2 reasons. First, energy intake equations are not accurate enough to detect the minor differences in energy expenditure that typically occur during a bulk. Second, different people will be able to achieve significantly different rates of lean weight gain, and it's very difficult to predict who will gain more muscle. For example, below is a plot showing the variance in lean body mass in the 2013 Garthe et al. study. The difference in growth is over 7-fold! On an optimized program, the variance shouldn't be *that* large though.

Figure 3. Relative changes in lean body mass (LBM) for athletes in the nutritional counseling group (NCG) and the ad libitum group (ALG).



Concretely, here's how to adjust energy intake based on the measured body composition change.

- If your weight nor body fat level is changing, you're likely in energy maintenance and you can add the target energy surplus to your energy intake. For example, if you were targeting a 7% energy surplus but the data indicate you're at maintenance, you should add 7% calories (by multiplying energy intake by 1.07). This scenario often occurs during a bulk at multiple time points, because energy expenditure should increase over time along with weight gain, reducing the energy surplus you are in and eventually turning your energy surplus into maintenance energy intake. You thus generally need to increase energy intake multiple times over the course of a long bulking phase.
- If you're already above the expected weight gain rate, strength development is good and you're not gaining any fat, it's unlikely you will benefit from a further increase in calories. Maintaining the current energy intake is normally the best approach.

- If your progress isn't great and you're not gaining fat yet, don't be afraid to push caloric intake up to the point that you gain some fat over time. The minimal amount of fat gain you can achieve is generally the sweet spot for a bulk.
- If you're consistently gaining more than a little fat week to week, decrease energy intake to avoid needless fat gain.

To give you an idea of how a highly successful lean bulk might look, here are the actual data of one of Menno's female clients. She had been in contest prep with a different coach who was far too aggressive with the energy deficit and implemented too much cardio, resulting in substantial muscle loss without even reaching a truly competitive body fat level for Figure. You'll see even though she was technically an advanced trainee, Menno kept pushing up the calories based on the limited fat gain and she put on a major amount of lean body mass within a 2-month period.

➢ Case study

Hyper-successful lean bulk

Cut or bulk?

So far we've seen that the effect of energy intake on muscle growth is minimal, but bulking may still be advantageous when you're lean enough. This begs the question: what constitutes 'lean enough'? Most people answer this question purely in terms of personal aesthetic preference: you aim to be in energy deficit when you want to get leaner, whereas you aim to be in energy surplus when you want to build more muscle. This is reasonable in that personal aesthetic preferences are obviously a major determinant of what anyone should do with their nutrition. However, there's also a physiological consideration to whether someone is lean enough to bulk: a person's body fat percentage and overall health status may influence how effective bulking is.

1. Anabolic resistance & MPS

Overweight individuals suffer from anabolic resistance in terms of protein balance. A 2019 review paper by Beals et al. and a 2021 review by Paulussen et al. concluded overweight individuals tend to have lower rates of total muscle and myofibrillar protein synthesis after eating than lean individuals. While not every study finds significant differences, the overall trend is decidedly negative. Beals et al. (2018) also found reduced myofibrillar protein synthesis levels in overweight vs. lean individuals after a strength training workout combined with protein consumption. There was no anabolic resistance to sarcoplasmic protein synthesis, which might partly explain why Hulston et al. (2018) found no evidence of anabolic resistance in overweight individuals for mixed muscle protein synthesis. Reduced muscle protein synthesis should logically reduce muscle growth, so it's paradoxical that we don't see reduced muscle growth in longitudinal experiments.

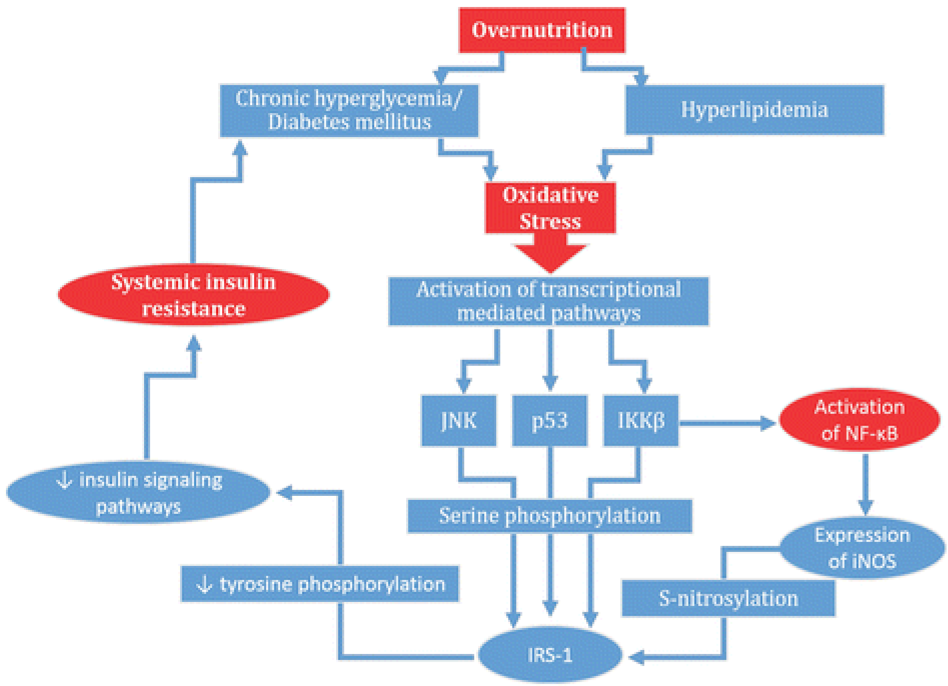
2. Insulin resistance & mitochondrial dysfunction

As you'll learn in the course module on carbohydrates, carbohydrate intolerance can impair nutrient partitioning and possibly lower energy expenditure in response to high-carbohydrate diets. Carbohydrate intolerance strongly correlates with body fat percentage: overweight individuals are far more likely to be carb intolerant. Some evidence suggests that insulin resistance is associated with poor nutrient partitioning, but there's no established mechanism by which insulin resistance itself would reduce muscle growth. Moreover, most of the evidence is associative and can therefore not establish causation. Stronger evidence exists for insulin resistance impairing mitochondrial adaptations and thereby possibly work capacity. We'll discuss the effects of insulin resistance in more detail in the course module on carbohydrates.

Another theory is that carbohydrate intolerance induces systemic inflammation on high-carb diets and it's the chronic inflammation that impairs neuromuscular functioning.

3. Chronic inflammation

Chronic inflammation levels are strongly linked to your body fat percentage: the more fat you have, the more inflammation you have [2]. Fat tissue secretes pro-inflammatory cytokines. Because blood sugar is inherently inflammatory by i.a. promoting reactive oxygen species (ROS) formation, insulin resistance caused by a high body fat level, especially high visceral fat storage around the liver, further contributes to the effect of body fat percentage on chronic inflammation.



The relation between diet quality, inflammation and insulin resistance. High blood sugar and certain fatty acid levels stimulate reactive oxygen species (ROS) production, causing inflammation. Inflammation in turn causes insulin resistance by i.a. metabolic stress on the pancreas. Insulin resistance exacerbates the rise in blood sugar levels, which causes a reinforcing effect on the whole cycle. Source

Much like cortisol, inflammation has a reputation of something inherently bad, yet cortisol's required for your body to function properly. Inflammation is effectively a signal for the immune system to pay attention to an area. This role is important during muscle growth. Strength training induces a considerable amount of inflammation in muscle tissue due to i.a. the damage to the muscle fibers. This inflammatory signaling initiates muscle repair and growth.

Interleukin-6 (IL-6) is a key player in the inflammatory regulation of muscle repair. Interleukins are cytokines: small proteins that act as signaling molecules. IL-6 is interesting in that it can act as both a pro-inflammatory cytokine in the blood but also as an anti-inflammatory myokine in response to muscle contraction.

Whether IL-6 is pro- or anti-inflammatory depends on its concentration and whether it was stimulated by muscle contraction or fat tissue. High resting levels of IL-6 indicate chronic inflammation, a generally undesirable condition that leads to erosion of many tissues as a result of an overactive immune system (auto-immune). Chronic inflammation has been linked to joint injuries, low testosterone levels and an impaired ability to gain muscle.

In rats, we have direct data demonstrating chronic inflammation is related to protein degradation and muscle catabolic signaling and consuming anti-inflammatory foods, including omega-3s, reduces muscle wasting during disuse.

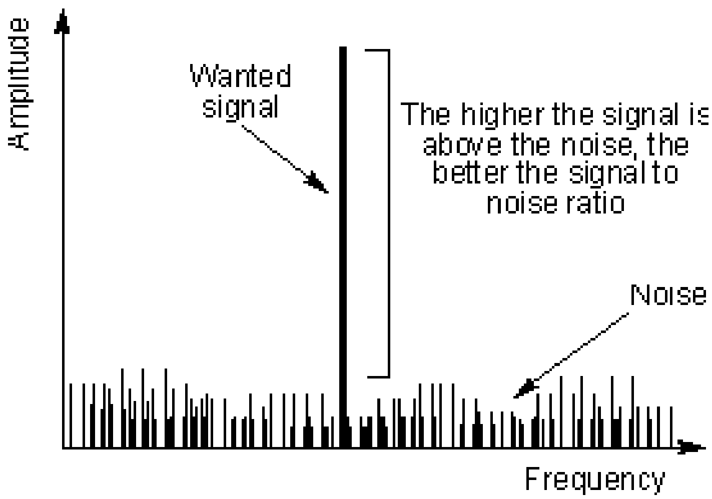
In a 9-month study on postmenopausal, strength training women, trunk fat mass correlated with resting IL-6 levels and negatively correlated with muscle growth. The more chronic inflammation the women had, the less muscle they gained. Higher resting IL-6 levels are also related to a faster strength loss with age.

Chronic inflammation, as measured by elevated C-reactive protein, also negatively correlated with muscle growth in a study of hospitalized elderly performing strength training.

Yet acute spikes in Il-6 are beneficial to activate satellite cells and start muscle repair. So IL-6 has a dual nature for muscle growth that corresponds with its dual nature in inflammation: short elevations are good but long ones are detrimental. This dual nature of IL-6 is perfectly illustrated in a 4-month study on young, strength training men from

Mitchell et al. (2013): resting IL-6 levels negatively correlated with muscle growth but post-exercise elevations in IL-6 positively correlated with muscle growth.

Inflammation thus seems to behave in a signal-to-noise relation with muscle growth. Chronic inflammation blunts the acute signal for muscle repair.



Several studies have found detrimental effects of supplementing anti-oxidants or anti-inflammatory drugs in young, exercising individuals, as this blunts the inflammatory signal for muscle repair and can thereby reduce muscle growth and strength development [2, 3, 4]. Excessive doses of vitamin C (> 1 g) and E are the most common sources of excessive anti-oxidant supplementation. Many multivitamin and pre-workout supplements can thus reduce your gains. (You'll learn more on this in the micronutrition module.)

In contrast, in the elderly some research found *increased* muscle growth, presumably because then it was more beneficial to lower chronic inflammation levels than it was to preserve the acute inflammation from exercise.

Interestingly, it seems that trained individuals have muscles that are more sensitive to inflammation and fat tissue that is less sensitive to inflammation, comparable to insulin sensitivity.

Because of the dual nature of inflammation with acute elevation being beneficial but chronic elevation being detrimental to muscle growth, we want low resting inflammation levels with clear post-exercise spikes to start muscle growth. You can achieve this with an overall anti-inflammatory diet, which we'll discuss in the course module on health sciences.

While excessive inflammation can clearly negatively affect anabolism, the relevance of systemic inflammation levels for young, healthy, exercising individuals remains to be determined. Most of the above studies finding negative effects on anabolism were in older individuals in poor physical health. Systemic inflammation likely only starts significantly interfering with muscular development above a certain threshold.

4. Recovery capacity

Possibly resulting from the higher inflammation levels and oxidative stress, being overweight can impair recovery capacity. Overweight individuals suffer more muscle damage after a given workout and subsequent neuromuscular recovery takes longer compared to lean individuals according to multiple studies [1, 2, 3, 4, 5]. We also see significant detrimental effects of obesity on muscle recovery capacity in animal and in vitro research. In addition to the effect of inflammation and oxidative stress, the obesity-related accumulation of saturated fatty acids in muscle cell membranes may weaken the muscle cells. Third, some combination of lipid overload, insulin resistance and chronic inflammation seems to reduce muscle satellite cell activity.

These studies also show that being *under*weight impairs recovery capacity. Women around 14-15% body fat had impaired neuromuscular recovery compared to healthy lean women [3, 4]. The detrimental effects of being excessively lean may be caused by suboptimal anabolic hormone levels, a persistent state of energy deficiency or a suppressed immune system.

Impaired recovery capacity needn't directly reduce muscular development, but it should logically reduce someone's maximum recoverable volume. Tolerating less volume in turn can impair long-term muscular development.

5. Hormonal health

In men, a high body fat percentage lowers androgenic anabolic hormone and growth factor levels, along with increased cortisol at higher body fat levels [1, 2, 3, 4, 5]. Male estrogen production occurs primarily via the aromatization (conversion) of androgens, notably testosterone, to estrogen. Aromatization largely takes place in fat tissue, which produces the aromatase enzyme for this conversion. As a result, higher body fat levels result in lower testosterone levels and higher estrogen levels in men. Some obese men even develop clinical hypogonadism (low testosterone), a phenomenon called Male Obesity-related Secondary Hypogonadism. At least above 12% body fat (no data on leaner individuals), male growth hormone and testosterone levels negatively correlate with body fat percentage [2, 3]. Correspondingly, fat loss generally increases men's testosterone levels. Growth hormone (GH) levels likely suffer due to higher insulin levels, which inhibit growth hormone production. GH reductions can be offset by higher insulin-like growth factor-1 (IGF-1) levels though, which may be more relevant than GH for muscle growth.

In women, most testosterone and estrogen production occur directly in the ovaries and the adrenal glands. As a result, there is no negative effect of higher body fat levels on testosterone levels in women. In fact, there is generally a positive effect of body fat on women's testosterone levels. Low body fat levels impair female bioavailable testosterone levels [2, 3]. However, higher body fat levels can still disrupt overall hormonal health. Female estrogen levels tend to be optimal in the range of 21-31% body fat. Growth hormone levels also tend to be higher at lower body fat levels in women, but the relationship is far weaker than in men.

When cutting, you may not fully benefit from the higher anabolic hormone levels until after energy restriction. During energy restriction in non-obese individuals, growth hormone levels do not change and the effect of energy restriction on female estrogen production is variable, suggesting the energy deficit cancels out any positive effects of being leaner.

In line with hormonal health, Ramlau-Hansen et al. (2007) found there is a negative dose-response relation between body fat percentage and fertility if your BMI is over 18.5 for both men and women. High body fat levels were associated with poor fertility. There was no negative effect of being leaner but a significant negative effect of BMI categories of 25+. If we convert these BMIs to body fat percentages using the aforementioned Deurenberg et al. formula for a 21-year old, the optimal body fat level for fertility should be below 18.6% for men and below 29.4% for women. The suggested optimum body fat level corresponding to a BMI of 18.5 is 10.7% for untrained men and 21.5% for women.

Being excessively lean is decidedly bad for sexual functioning, however. Any contest competitor can tell you that contest prep is bad for libido. Anabolic hormone levels generally tank in the later stages of a prep, sometimes to clinically low levels [1, 2]. Women also often lose their menstrual cycle (amenorrhea).

Low anabolic hormone levels should logically reduce muscle growth. However, these effects typically take months to manifest and within the physiological range, the effects are nothing like those of anabolic steroids. We'll discuss the effect of sex hormone levels on muscular gains in more detail in the course module on fats.

Empirical evidence

While one mouse study found that major fat gain, resulting in insulin resistance, reduced muscle growth in response to a functional overloading program compared to control groups, subsequent human research has not found any negative effects of high body fat levels on exercise-induced muscle growth. The factors we discussed above thus don't seem to significantly affect muscle growth. Interestingly though, multiple studies did find reduced strength gains.

- Blake et al. (2000) found no difference in fitness improvements between 89 obese vs. healthy weight women during an exercise program, although the program was not dedicated to strength training and neither group experienced any positive body recomposition.
- Pescatello et al. (2007): In this 12-week study on young adults, the gains of 687 overweight (BMI 29) and healthy weight individuals (BMI 22) were compared during a strength training program. Percentage gains in strength (MVC and 1RM) were greater in the healthy weight group than the overweight group, but absolute gains were similar between groups, as the overweight group had higher baseline strength. The percentage gain in muscle size (CSA) was equal between

groups, but in absolute terms, the overweight individuals gained more muscle, as they started out with a higher level.

- Peterson et al. (2011) investigated the effect of body fat level on strength training adaptations in 634 non-obese, young, healthy men and women. All participants completed a 12-week training program while maintaining their habitual diet. Participants that lost weight were excluded, so this was effectively a study on bulking trainees. There was a negative correlation between baseline body fat mass and strength: men with higher starting body fat levels gained less 1RM strength than those with lower body fat levels in the analysis. In women, there was no correlation between baseline body fat level and strength gains, possibly due to their superior metabolic health (see course module on sex differences). Baseline body fat level was not related to muscle growth.
- Marcus et al. (2013) investigated the effect of intramuscular (IM) fat content on muscle functioning in 70 elderly individuals during a 12-week mixed exercise program involving some strength training. Only the 33% participants with the lowest IM fat content experienced a significant increase in strength relative to muscle size. The participants with more fat in their muscles did not. No group managed to gain lean body mass.
- Nicklas et al. (2015): In this 5-month study of 126 overweight elderly, individuals that were leaner when the study started (i.e. had a lower body fat percentage) experienced greater improvements in muscle strength, muscle quality and power during the strength training program. These improvements did not correlate with the rate of fat loss or initial muscle mass, indicating they were not confounded by energy intake or baseline training status. The effect of initial body fat level on muscle growth was unfortunately not assessed.
- Ribeiro et al. (2022) had 99 older women participate in a 24-week strength training program, divided into 3 groups based on their initial fat mass: 'low' (32%

BF), ‘medium’ (41% BF) or high (46% BF). Gains in strength and muscle mass did not significantly differ across the groups. However, the 'low' body fat group interestingly achieved better body recomposition than the 2 overweight groups due to greater fat loss, in contrast to most studies, which find that it’s easier to lose fat and retain muscle for individuals with more fat to lose.

- A 2022 meta-analysis by Lopez et al. in untrained, overweight individuals found no significant effect of baseline BMI on strength training induced muscle growth, although most individuals ended up losing fat and gaining very little muscle, so they were effectively cutting.

So what’s the ideal body fat range?

Your body fat level does not seem to directly affect muscle growth. However, strength gains are worse in overweight individuals in multiple studies. This may not be a concern for metabolically healthy athletes, but there are multiple lines of evidence suggesting muscle growth might not be *maximized* either at high body fat levels in practice. Overweight individuals have been found to have anabolic resistance to protein, impaired muscle functioning, worse recovery capacity and lower anabolic hormone levels, which could impair someone’s maximum volume tolerance.

The safest body fat range for maximum muscular gains is likely in between contest shape and being overweight. Based on the available data, we estimate the optimal range to be 9-17% for men and 19-28% for women. If you’re a woman and you lose your period at a certain body fat percentage, or it becomes irregular, that probably corresponds with the lower limit of the optimal range for you. The upper end of the range for both sexes is roughly the point where they start getting a protruding belly. For a muscular man that means he should ideally never lose all his ab definition. Abdominal fat storage is accompanied by visceral fat accumulation, which rapidly increases the negative effects of a higher body fat percentage on metabolic health. Women have a lot more leeway than men in terms of adding fat due to their greater metabolic health and different sex hormone regulation. Women's fat storage will generally result in more feminine curves before turning into a belly.

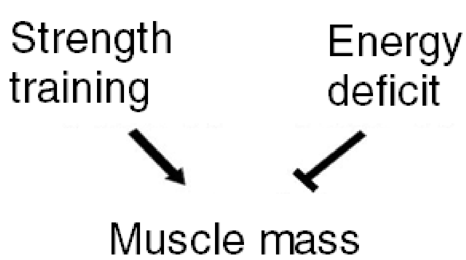
If you're not within the ideal body fat range, the first step for long-term body recomposition progress is ideally getting to that range. Bulking to higher body fat levels risks not only your health but also impaired gains and loose skin later. Of course, if you have good reason to bulk up to higher body fat levels, such as a higher weight class or being a linebacker (or personal preference), you should do that instead. You can likely offset most disadvantages of higher body fat levels with an optimized diet, a lot of muscle mass and a healthy lifestyle. The direct short-term effects of higher body fat levels are minimal compared to many other factors, like your lifestyle, your nutrition and your training program design. Your body fat level is clearly a matter of finetuning rather than primary importance for your gains.

Within the optimal range, the decision whether to cut or bulk is simply a practical and psychological question.

If you think these body fat ranges are unrealistically low, your frame of reference may be excessively influenced by the standards of contemporary society. In traditional hunter-gatherer societies like the Hadza, the average body fat percentage of men is 13.5% and that of women is 20.9%. And that's long after this culture had already discovered many of the indulgences of Western civilization, like tobacco and alcohol. Since strength trained individuals should carry a lot more muscle mass and burn a lot of energy during their training, it’s very doable to stay below these values year-round with a healthy lifestyle. Of course, it’s not always easy in today’s society.

Cutting

Everyone would like to be lean, but your body does not share your enthusiasm for rapid fat loss. It much prefers some energy reserves hanging around. In energy deficit, homeostatic mechanisms activate to decrease energy expenditure. Negative energy balance in lean individuals inhibits the activity of the hypothalamic-pituitary-thyroid, -gonadotropic and -somatotropic axes and activates the hypothalamic-pituitary-adrenal axis [1, 2, 3, 4]. That is, an excessive caloric deficit will cause thyroid hormone, growth hormone, insulin, insulin-like growth factor-1 (IGF-1) and testosterone production to decrease. Instead of all these nice anabolic hormones, your body will produce more adrenalin, noradrenalin and cortisol. Cutting makes your body preserve energy and stimulates you to find food *pronto*. One mechanism to lower energy expenditure is reducing muscle protein synthesis and thereby muscle growth. If the energy deficit is severe enough and the muscle tissue does not have enough anabolic signaling, the body will catabolize the muscle tissue for fuel.



To lose fat and not muscle, we need to make sure there is a greater stimulus to maintain/build muscle mass than to catabolize it.

As a result of the body's adaptive processes that try to maintain energy homeostasis, progressively greater energy deficits result in less and less additional fat loss. A study comparing the difference between 3 months of dieting with a 25% caloric deficit or a VLCD of 890 kcal a day showed that although the VLCD lost more total mass, the ratio of muscle to fat loss was also considerably higher and this discrepancy didn't balance out over the 6-month study period. Furthermore, the fat lost was not proportional to the size of the deficit. An 890 kcal diet creates a deficit well over twice as large as a 25% deficit, but it resulted in less than twice as much fat loss. The finding of diminishing returns in fat loss to the size of energy deficit has been replicated in many other studies [e.g. 1, 2].

When you get to really extreme energy deficits, lowering your calories further may barely increase fat loss at all. A randomized controlled experiment investigating the effects of different very low-calorie diets (VLCDs) with groups eating 420, 660 or 800 Calories per day for half a year found "no significant differences in weight losses or changes in body composition among the three dietary conditions at the end of treatment". Considering they studied obese women, 800 kcal a day doesn't even constitute such a drastic caloric deficit. A review paper concluded that "VLCDs and low-calorie diets with an average intake between 400 and 800 kcal do not differ in body weight loss." The lack of any difference in fat loss in these studies is likely in large part attributable to lack of diet adherence combined with significant adaptive thermogenesis in the extreme deficit groups.

To balance our desire for fat loss with our desire to maintain or build lean body mass, there is an optimal caloric deficit for body recomposition. Let's look at how to find this sweet spot. In the following table we summarized the literature on the effect of weight loss rate/energy deficit on body recomposition in strength training individuals. Collectively, these studies quite clearly show that someone's energy deficit should depend on someone's body fat percentage. Obese individuals are at minimal risk of excess muscle loss even during crash dieting without strength training [2]. Multiple meta-analyses [1, 2, 3] in overweight individuals found that fat-free mass loss during dieting is not significantly affected by the rate of weight loss, only by the total amount, or that any greater lean body mass losses during faster weight loss are generally compensated for by the time saved to afterwards regain the lean body mass. Correspondingly, overweight individuals suffer minimal decreases in myofibrillar protein syntheses rates in energy deficit, in contrast to leaner individuals. In other words, overweight individuals can still lose weight productively very fast.

At lower body fat levels, a moderate energy deficit has to be employed to spare muscle mass. For example, a 2023 study on national level bodybuilders compared a 2.4% to a 1% weight loss rate during a 6-week cutting diet. The aggressive group lost almost twice as much fat: 7 kg vs. 4 kg. However, this came with the loss of a whopping 5 kg fat-free mass compared to losing only 0.8 kg, as per InBody scans. Body circumference measurements confirmed that the evidence-based group maintained their arm, chest and thigh size better. Due to the muscle loss, the faster weight loss group didn't go down in body fat percentage faster than the more moderate group(!) Both groups maintained their estimated squat and bench press 1RM strength, indicating that strength maintenance is often not enough to preserve muscle mass during a cut. In that sense, even the slower weight loss group was probably already pushing the limits of weight loss speed in this study. Indeed, if we look at other research on elite athletes, we see that a weight loss rate of 0.7% per week results in more favorable body recomposition than a weight loss rate of 1%. The slower cutting group gained more bench press strength and achieved positive body recomposition, in contrast to some (insignificant) muscle loss in the faster cutting group, with comparatively little difference in fat loss. Taking the diet slow often pays off for leaner individuals.

See the following research overview for a compilation of studies that compared different rates of weight loss or energy deficit.

➢ Research overview

What's the optimal rate of weight loss/energy deficit?

Based on the above data, we have estimated the optimal deficit and rate of weight loss as a function of body fat percentage in the following table. The general principle is that the greater the risk of muscle loss, the more conservative you should be with the energy deficit. The risk of muscle loss in turn is determined chiefly by someone's body fat percentage, with greater risk at lower body fat levels, but also the person's overall program quality, training status and lifestyle factors.

Category	Fat percentage (%)		Optimal deficit (%)	Maximum weekly weight loss (% BW)
	Male	Female		
Contest prep	< 8	< 14	2.5 – 7.5	0.5
Athletic	8 – 15	14 – 24	5 – 25	0.7
Average	15 – 21	24 – 33	20 – 35	1
Overweight	21 – 26	33 – 39	30 – 50	1.5
Obese	26+	39+	maximum	N.A.

For example, a 70 kg male at 15% body fat may want to cut on a 20% energy deficit and thus multiply his maintenance energy intake by 0.8 to get his target energy intake. He should not consistently lose more than 70 × 0.7 / 100 = 0.5 kg per week to avoid muscle loss.

Note that the weekly weight loss guideline is a *maximum*, as the less weight you lose given a certain amount of fat loss, the better(!) In the above example, surely he would rather get to 10% body fat at 68 kg than at 60 kg.

You should always think of weight change as a *percentage* of body weight change and energy balance as a *percentage* of maintenance energy intake. This finetunes the diet to the individual's bodyweight and metabolism. Many one-size-fits-all diets fail, because they set calories at some predetermined level without considering the individual's weight or metabolism. This is also why the often-heard recommendations of cutting on a 500-calorie deficit or losing 1 to 2 pounds a week are arbitrary at best. These numbers may work as averages of averages for some populations of people who are otherwise clueless on how to design a diet, but as general laws they fail. 2 Pounds a week is extremely drastic for a female Bikini competitor yet slow for many obese men. Likewise, a 500-kcal deficit achieves very different results on a person with a maintenance intake of 2000 kcal compared to a person with a 4000-kcal maintenance intake. The same goes for bulking. Using percentages rather than absolute numbers ensures that your guidelines can apply to all individuals.

When you start a cut, you can go straight into your target energy deficit. There's thus no need for a maintenance phase or anything like that. Gradually decreasing your energy intake as opposed to abruptly decreasing it, given the same cumulative energy deficit and protein intake, does not improve fat loss, fat-free mass retention or strength development.

As a diet progresses, you at some point most likely have to adjust energy intake to maintain the optimal energy balance and fat loss rate, as the dieter's metabolism will adjust. Based on the above data, given average nutrient partitioning, the following table summarizes someone's expected energy deficit based on their observed weight loss rate. You can use this chart as a rough guideline to estimate what energy deficit you are in based on your weight loss rate so that you know how to adjust your energy intake to get to your desired energy deficit.

Observed weekly bodyweight loss rate (%)	Estimated energy deficit (%)
0.3	10
0.7	20
1.1	30
1.5	50

If you are already lean, you often have to decrease energy intake progressively during a cut, because energy expenditure decreases due to weight loss and adaptive thermogenesis. For example, if you stop losing any fat while you wanted them to be in a 20% deficit, you have to decrease energy intake by at least 20% to put yourself back in your optimal deficit. Ideally of course, you monitor your body composition progression along the way to prevent complete plateaus. If you notice fat loss slowing down and you expect yourself to be in only a 5% deficit currently, you should decrease energy intake by at least 15% of maintenance to re-optimize your energy deficit. To put yourself from an expected 5% deficit into a 20% deficit, you divide current energy intake by 0.95 and then multiply it by 0.8.

However, muscle growth and improved work capacity during training may increase energy expenditure enough in some cases to offset the metabolic slowing and thereby allow you to increase energy intake. This mostly happens in overweight individuals and novices who can start off with an aggressive energy deficit and over time have to transition into a more moderate energy deficit as they get leaner. For example, if a previously overweight individual keeps losing weight at a rate of 1.5% of bodyweight per week, they're probably still in about a 50% energy deficit. If you want them to be in only a 30% deficit, you should divide their current energy intake by 0.5 and then multiply it by 0.7.

As an additional guideline, even in the worst case scenario you should not see muscle loss of more than 25% of weight loss, as not even competitive bodybuilders typically lose more muscle than that during contest prep [1, 2].

When interpreting weight loss rates, beware that many people experience stair wise rather than linear weight loss rates over time. As opposed to simple relatively linear weight loss over time, many people's weight can remain relatively stagnant for around a week beware it suddenly drops a significant amount and this pattern can consistently repeat itself over time throughout a cut. This sudden weight loss event is informally known as a 'whoosh'. The mechanisms for this sudden stair wise weight loss are not well-defined. The most popular theory is that the weight loss is water. During weight loss, adipose tissue can increase in water content [2]. Chronically elevated cortisol levels during dieting may also cause an increase in body water storage ('bloating'). Since the body can't just keep storing more and more water, after a certain threshold or after certain events, this water seems to come off in a 'whoosh'. Regardless of why the whoosh effect occurs, it's important to keep in mind when interpreting your weight loss data. If you notice pronounced non-linear weight loss rates, you may need to calculate the average weight loss rate over the past 2 weeks to get a representative idea of how fast you are really losing weight.

Summary: optimizing energy intake

Here's a summary of how to determine energy intake. Note that you can write any percentage as a factor, e.g. 20% deficit = 0.8 energy balance factor, 10% TEF = 1.1 TEF factor.

1. Cunningham (1991) BMR = 370 + (21.6 × *FFM in kg*)
   FFM = BW × (1 - BF% / 100)
2. Conservatively estimate the daily life physical activity level (PAL) using the table below.

	PA Values for Different Physical Activity Levels [65]			
Gender	Sedentary	Low active	Active	Very Active
Men	1.00	1.11	1.25	1.48
Women	1.00	1.12	1.27	1.45

3. Estimate TEF in between 1.1 and 1.25 based on diet quality and BF%.
4. On non-training days, total daily energy expenditure (TDEE) = BMR × PAL × TEF
5. Resistance training (RT) EE = 0.1 kcal/kg/min of intensive training
6. Training day TDEE = REE + RT EE × TEF
   = (BMR × PA + RT EE) × TEF
7. Determine the optimal energy balance factor (EBF) based on BF% and training status.
8. Average target total daily energy intake = EE × EBF

Very lean individuals, such as those in contest prep for a physique show, may need to apply an adaptive thermogenesis multiplier of 0.8 – 1.

It's important to understand the above math. However, once you do, there's no need to do it all by hand, so here's a calculator to do the math for you. For optimal user-friendliness, download the file (File → Download → Microsoft Excel).

➢ PT Toolkit

Energy intake calculator

For optimal user-friendliness, ***download*** *the file (File → Download → Microsoft Excel).*

Measuring progress

The initial energy surplus or deficit estimation is just the starting point of any diet. After this, formulaic estimations become redundant, since you have individual level data. To maintain the desired rate of body composition change, you will need to adjust energy intake in response to the observed body composition change. The aforementioned tables with recommended energy intakes in relation to bodyweight change can serve as a useful reference here. For example, when you observe no weight or body fat percentage change and you aimed for a -0.7% BW loss rate, you should lower energy intake by approximately 20%. You will need to monitor your metabolic adaptivity – how quickly you lose/gain bodyweight in response to a given caloric deficit/surplus – to finetune this estimate. People with a very adaptive metabolism may need more than a 20% change in energy intake from maintenance level to achieve that rate of weight loss.

Most importantly, progression should always be the benchmark by which to adjust anything in the program. If you are losing fat at an excellent pace and you are rapidly gaining strength but your bodyweight isn't decreasing, you should absolutely not decrease energy intake to force a certain amount of weight loss. In fact, logically, given a certain amount of fat loss, the less weight you lose, the better, as this indicates positive body recomposition. Don't fix what isn't broken.

To optimize your energy intake in response to the observed body composition change, you will need to monitor 3 things.

1. Your energy intake.
2. Your weight.
3. A measure of your body fat level.

Macro tracking

A common and convenient way to track your macros is to use a website or app. There are many and in principle they're all fine. MyFitnessPal.com is probably most popular, but Cronometer and MyNetDiary are better on many fronts.

When using such an app, many people make a major mistake. They use the app's database. Much like using those body fat percentage estimation collages from the internet, most apps have a database that is compiled from completely untrustworthy sources. In fact, often anyone can input things in the database (crowdsourcing).

And that's just genuine error. MyFitnessPal.com has been accused of manipulating its database in the past to try to make people eat less, so that they lose more weight and are more successful when using the app.

Moreover, you commonly see foods in such a database having no fiber, no carbohydrate or no calories. In many of such cases, the macros of the food are completely wrong.

Instead, input your own foods and meals into your log based on the nutrition labels of your food. They should be reasonably accurate and they account for regional variation. The same dairy product, for example, can vary enormously in its carbohydrate to protein ratio, even when fat content is the same. In South America dairy products tend to be far higher in carbs than in Europe.

When you log your macros this way, make sure your macros are on target, not total calorie intake as calculated by MyFitnessPal. MFP does not calculate total calorie intake correctly: it is systematically wrong by over several percent. Cronometer and MyNetDiary should be correct with their calculations.

Note that the nutrition label generally gives the nutritional composition of the food in its packaged state. That means foods like chicken and rice are often uncooked and you should weigh them that way. As a guideline to avoid confusion, most raw meats, poultry and fish have ~20 g protein per 100 g and most raw starches like rice have ~350 kcal per 100 g.

Also, note that in the United States and most of America, the nutrition label lists total carbohydrate content, which means dietary fiber is included in that number as per FDA law. In the European Union, the nutrition label lists carbohydrate and fiber separately. So something with 80 g carbohydrates, of which 20 g are fiber, will be listed as having 60 g carbohydrates in the Netherlands, as opposed to 80 g in the US.

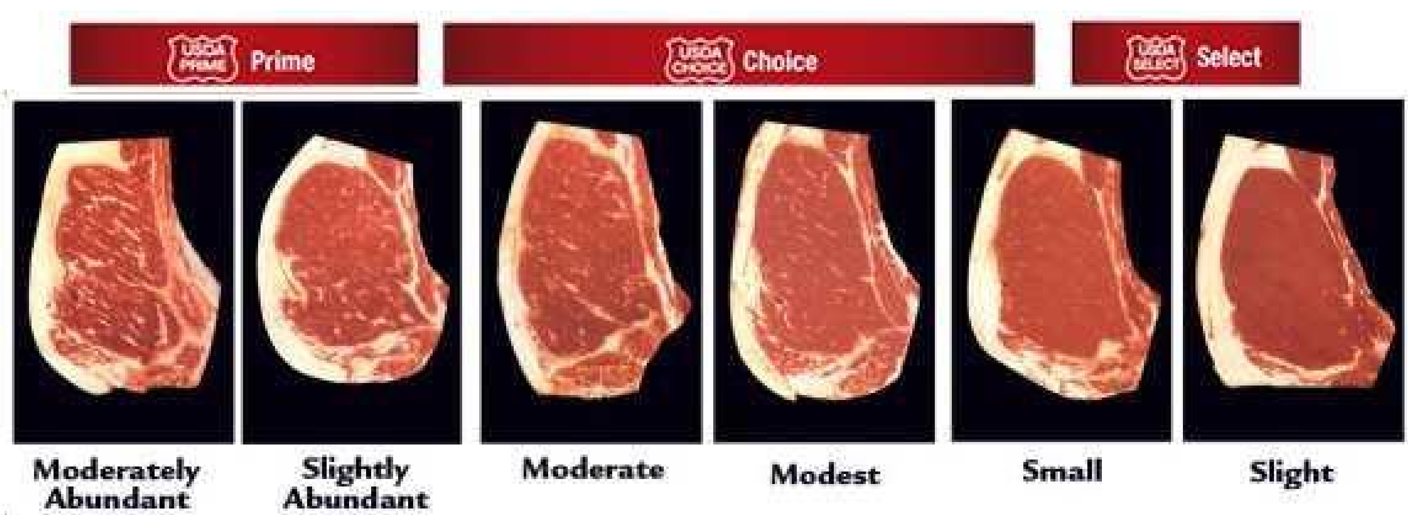
If your food doesn't have a nutrition label, use the one database to rule them all: the USDA's FoodData Central. This is one of the few scientifically validated, public databases that is practical to use. Conveniently, Cronometer and MyNetDiary have the USDA database built into their own database, so in this case you can safely use the app's database, if you don't have a more accurate food label available.
For Norwegians specifically, there is also The Norwegian Food Composition Table.
For the Dutch specifically, there is also the Dutch Food Composition Database (NEVO).

Sometimes, you have neither a food label nor a corresponding entry in any database. In that case, you may have to estimate the macros to the best of your abilities using the closest possible reference values.

It helps to know that ingredients should be listed in descending order of weight according to FDA and European law. For example, let's say you have a cookie with the ingredients: peanuts, coconut flour, sugar, sodium, E2170. E-numbers are food additives approved by the European Food Safety Authority and you can generally assume they're irrelevant for all intents and purposes. Sodium can also be ignored in terms of weight. So we have 3 ingredients. That means this cookie has 33% or less sugar.

Estimating the calories in meat

When you have to estimate the macronutrient composition of meat, you can use the USDA marbling guide shown below to estimate its fat content.



Marbling Score	Intramuscular Fat, %
Slightly abundant	10.13
Moderate	7.25
Modest	6.72
Small	5.04
Slight	3.83
Traces	2.76

If you want to eat lean meat but can't purchase 95% or leaner meats, you can significantly reduce the fat content by letting the fat drain out of the meat during pan broiling. For 20% fatty meat, you can then blot the cooked meat with a paper towel to take off several more grams of fat. If you don't care if you reduce the flavor, you can then cut the fat content a further ~50% by rinsing off the meat with water: see the table below.

Calorie and Fat Comparison for Ground Beef				
	80 % lean (4 oz. uncooked)		90 % lean (4 oz. uncooked)	
Cooking Method	Calories	Fat (g)	Calories	Fat (g)
Uncooked	287	22.6	199	11.3
Pan-broiled, medium well	230	15	175	9.2
Pan-broiled, blotted	217	14		
Crumbles, blotted	191	11	196	10
Crumbles, blotted, rinsed and drained	130	5		

Source

How to weigh yourself

To adjust your progress based on your weight change rate, you obviously have to monitor your weight. You should weigh yourself daily, because a single weigh-in has large variance and daily weight fluctuations mean practically nothing. Several factors impact your day-to-day weight that say nothing about your physique.

- Mass in your digestive tract. Just having drunk a few extra glasses of water that you haven't excreted yet could already make a several hundred gram difference in weight. Food mass in your digestive tract can make an even bigger difference.
- Water retention. Your body is mostly water and the total water weight can and does vary on a daily basis as a result of i.a. your consumption of water and minerals, sodium in particular.
- Glycogen storage. Changes in i.a. carbohydrate intake can impact your total body's glycogen storage level. Each gram of intramuscular glycogen attracts ~3 g of water into the muscle, which can add up to a weight change of several hundred grams.

Because of these factors, you should only pay attention to your weekly average weight and its change over time. The more weigh-ins you have, the more reliable the weekly average and its change from last week.

You should weigh yourself fasted in the morning after having gone to the bathroom. Weigh-ins later in the day are far less accurate, as they're confounded by what you ate and drank in the meantime, how much you sweat, how often you went to the bathroom, etc.

Body composition tracking

When tracking an exercising person's physique progress, there's a very elementary point that cannot be overstated: you need to distinguish between weight and body composition.

Visual estimation

Here's an example of one of Menno's clients that performed a DXA scan every ~3 weeks. His weight hovered around 83 kg (183 lb) throughout these 2 months and 17 days, so if he had only monitored his weight, Menno may have concluded he wasn't progressing at all, when in fact his body fat percentage decreased by 4.3% and he gained 3.1 kg (6.8 lb) of muscle, which is excellent progress for an advanced trainee with over 20 years of training experience. (You can find the anonymized DXA scan overview here.)

14 %   13.4 %   12.2 %   10.3 %

BAYESIANBODYBUILDING.COM

The second point you should note is that progress is very difficult to assess visually. Simply looking at your photos doesn't cut it for accurate measurement. It can suffice to calculate the parameters for your initial program, but it's just not accurate enough to track short term progress. Between photos 1 and 2, you may be forgiven to conclude that he looks worse, when in fact this is the period he gained most muscle mass. The difference in visual appearance is simply because of the lighting. Differences in lighting can easily have more effect on someone's look in a photo than *months* of progress.

Here's an example of Menno backstage during one of his earliest shoots. There are literally milliseconds between the 2 photos and neither photo has been edited in any way. They're from a rapid-fire camera that takes each photo with and without flash.

Before and after turning the camera's flash off

Add to this differences in someone's pose, water retention, glycogen storage, intramuscular fat storage and abdominal distension, and it's clear that subjectively assessing your progress photos is a crappy way to monitor progress (but a very good way to convince the gullible masses that you achieve spectacular before-after results). Specifically, we tend to majorly underestimate body fat percentage.

The only thing we can really discern well is muscle definition. This is why you almost never see before-after photos of someone bulking. For the untrained eye, a natural trainee will often only look worse and worse throughout a bulk phase, at least in shirtless photos.

So what do you do if photos are unreliable, the scale is incomplete and you don't have access to fancy equipment like a DXA scanner?

You have several options.

Note: if the difference between error and bias is not clear to you, revisit week 1's DIY research topic before continuing.

The measuring tape

The main benefit of the measuring tape is that it's cheap and readily available. However, using a regular tape is prone to positive bias, as people will be tempted to tighten the tape more if they don't see the desired results. To avoid this, it's important to use a tape that standardizes the tightness with a button. These kind of measurement tapes are accurate to track the circumference of various body parts over time.

However, accuracy is not the main problem. The main problem is that the circumference of any body part tests both fat and muscle mass. For example, if someone's biceps circumference isn't decreasing on a cut, is that a sign they're not losing fat and the calories should decrease or is it a sign they're experiencing positive body recomposition? During a bulk, does an increase in biceps circumference mean muscle growth as planned or just fat gain? To separate between muscle and fat mass as well as possible, the waist is generally the best location to measure. There is a relatively large amount of fat storage in this area and muscle growth is limited. Other locations are too strongly confounded by lean body mass changes. Even for the waist it is a mistake to assume that *all* changes will be due to changes in fat mass.

Throughout their training career, it is not uncommon for people to gain several inches on their waist as the muscle mass in their 'core' increases, especially if they're doing a lot of abdominal training. This is generally not a problem for week-to-week changes though.

Someone's waist measure is a reasonable indicator of changes in their body fat level, but you cannot accurately calculate someone's body fat *percentage* based on their waist circumference. Even in overweight individuals the relation between waist circumference changes and fat loss is weak and the waist-to-hip circumference ratio is a mediocre predictor of total body fat level. The famous US Navy method is also horribly inaccurate to estimate body fat percentage and changes therein even in soldiers, the very population it was designed for. Thus, changes in someone's waist circumference can only reasonably be used as a qualitative measure of fat loss, not a quantitative one: you can see if it's increasing, stable or decreasing, but you cannot infer from this how much fat mass is changing.

A second confounder of waist circumference changes is abdominal distension. Being bloated due to high water retention can increase your waist circumference by several inches without changing your body fat percentage. Stress, sleep deprivation, food intolerance and improper fiber intake can all result in bloating. Women can experience some degree of bloating throughout their menstrual cycle because of changes in the hormone levels that govern water retention, like estrogen.

The most obvious source of abdominal distension is simply food volume. This is something that people that have never been really lean often underestimate. The food in your gut will make your gut protrude after eating. The leaner you are, the more pronounced this effect is, simply because the relative change in waist circumference is greater when your waist is smaller. Below is an example of extreme bloating and (intentional) abdominal distension from Spencer Nadolsky.

Athlete: Spencer Nadolsky

You can mitigate the effect of abdominal distension on your waist circumference in several ways.

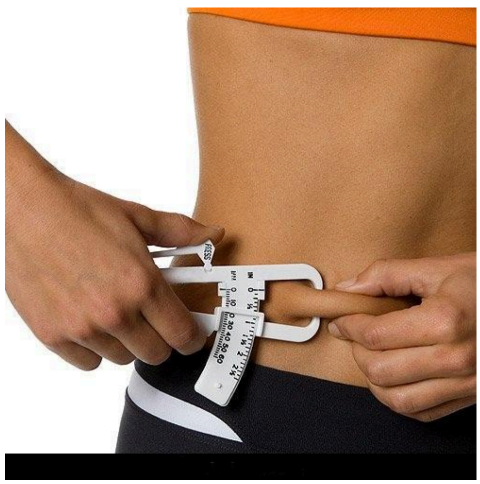
1. Always measure your waist circumference fasted in the morning after having gone to the bathroom.
2. Measure yourself more than once a week. (Twice generally suffices, but the more, the better.)
3. Measure yourself either with your abs maximally distended or with your abs maximally flexed. Most people prefer the flexed measurement for obvious vanity reasons. Anything in between will leave room for false positives by sucking in the gut (and vice versa, less commonly).

Moreover, the waist alone may not suffice as a measurement location in women, since women generally store more fat on the lower body. Men tend to have an apple shaped body fat distribution with very centralized fat storage, whereas women have a more pear shaped body fat distribution. This sex difference in body fat distribution pattern is largely genetic. Especially at lower body fat percentages, it is not uncommon for women to lose very little fat, if any, from their waist in the short term. Most of the fat will be coming off their lower body. In this scenario, it's a good idea to track hip or thigh circumference in addition to waist circumference.

Overall, the measuring tape is surprisingly useful for tracking changes in body fat level due to its low cost and ease of use. You cannot accurately measure short-term muscle growth or body fat percentage with a tape measure, but with properly standardized measurements, you can get a decent idea of whether someone is losing, gaining or maintaining their body fat level from one week to the next. You should ideally use a tape with a tightness regulator. Men should measure their waist circumference, as it's the location that's least confounded by muscle mass and most strongly correlated with total body fat mass. It's arguably the only useful location to measure, in fact. In line with their less centralized body fat distribution, women, especially lean women, often need to measure their thigh and/or hip circumference as well.

Skinfold calipers

Skinfold calipers measure the thickness of a skinfold you grab. Pinching your skin together in a skinfold allows you to measure the thickness of the subcutaneous fat layer under the skin. The thickness of the fat layer on various locations on your body can then be used to estimate total body fat percentage using formulas derived by comparing these data with validated measures of people's body fat percentage.



Skinfold thickness measurement using manual calipers.

Contrary to popular belief, skinfold calipers are not too bad at predicting body composition in sedentary individuals as well as bodybuilders, both across and within individuals [2]. Skinfold calipers are often more reliable at measuring someone's body composition than traditional ultrasound measurement [2] and can approximate DXA scan accuracy, though newer ultrasound methods have been found to outperform skinfolds in certain populations [2]. Even better is that calipers suffer from error but very little bias. They are thus robust against changes in water retention, provided that you can be consistent with your measurement technique. So simply taking repeated measurements and taking the average (or median or mode, if there is large variance) tends to improve reliability greatly.

In fact, the primary source of bias comes from the translation of the skinfold thicknesses to body fat percentage. Equations that estimate body fat percentage from skinfold thickness data tend to systematically underestimate the body fat percentage of athletes and different equations can produce wildly different body fat estimates. This is where many of the values of guys claiming they're 2% body fat or something like that come from. Reality check: men have an essential body fat percentage level of ~3-5%; for women it's ~8-12%. 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. So normally the only men with a body fat percentage below 3% and women below 8% are in a coffin.

The solution is simply not estimating body fat percentage based on the skinfold thickness data. People tend to be overly concerned – obsessed is the right term here arguably – with their numerical body fat percentage, when all you really need to know in practice is if your skinfold thicknesses are going down or up. This makes it a qualitative test, meaning you only know whether you're losing or gaining fat but not how much, but if you're tracking someone's weight, you already have a quantitative measure of their weight change.

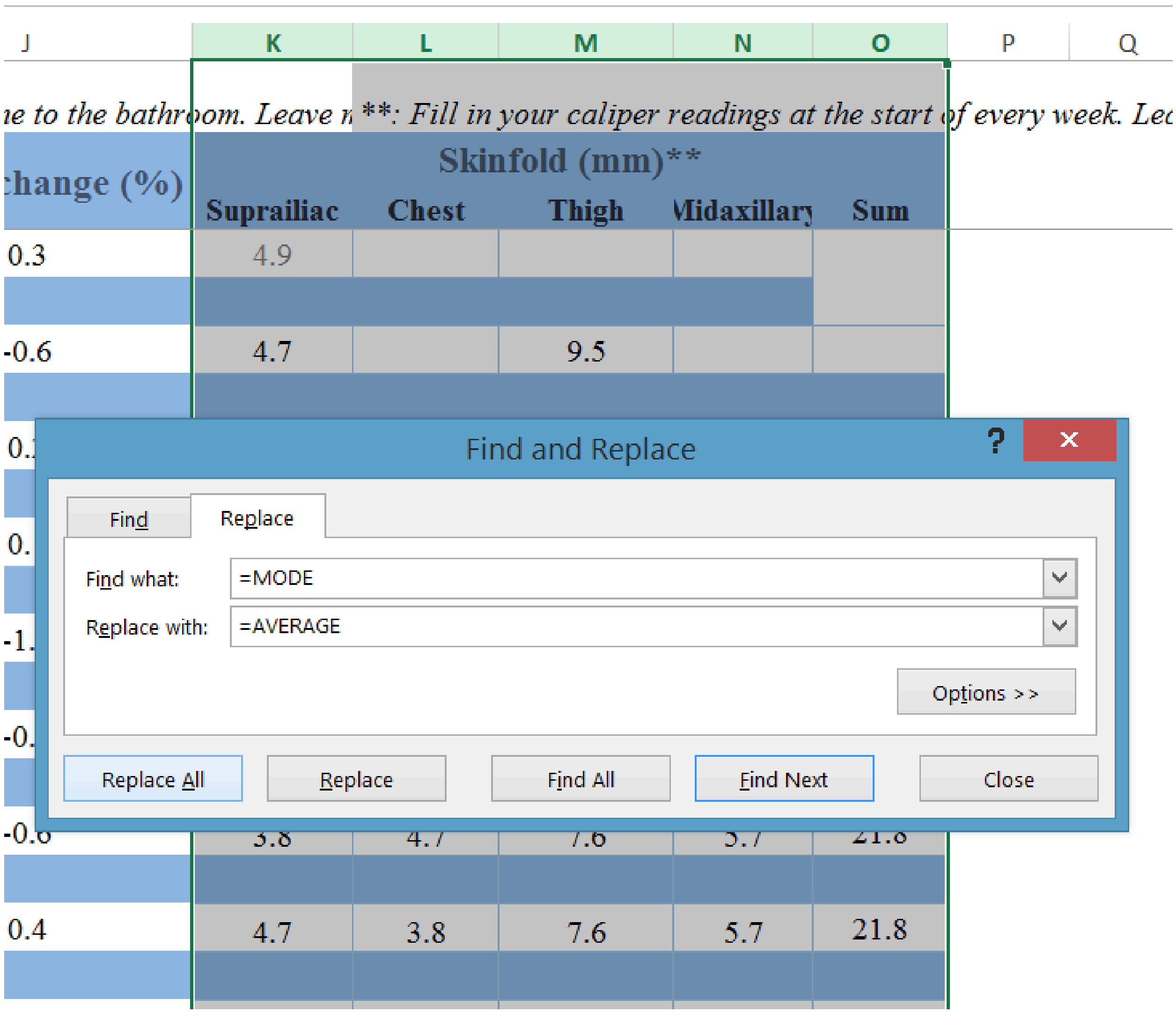
Due to the difference in body fat storage pattern, men and women need to measure different skinfold sites. For men the umbilical and suprailiac sites are most reliable and together generally already explain well over 90% of the variance in body fat percentage changes. Most women will need to add the thigh and calf sites to reach that level of reliability.

Most importantly, you need to be flexible in the locations you measure. You'll find that some people have a difficult time becoming proficient with the calipers and that people vary in their fat storage pattern. Here are a few things you can do when the caliper measurements are internally inconsistent or highly variable:

- Use the mean, mode or median instead of the direct measurements.
- Switch skinfold sites.
- Use the sum of skinfolds or the sum of the means/modes/medians.

Here's a case study of one of Menno's clients to show how you sometimes have to adapt your skinfold tracking system. We started off just measuring the suprailiac and the umbilical sites, but these did not prove reliable. The reason was that he couldn't figure out well how to use the calipers, i.e. measurement error. So Menno added the thigh, which again didn't prove reliable. So Menno asked for a video of how he performed the measurements. It turned out he seemed to vary between various measurement techniques, but within those techniques he was perfectly consistent. This means you can expect not just error but bias in the measurements and the average value won't reflect the true trend very reliably. Here the mode is perfect to measure his progress. Indeed, when you switch from the average to the mode, you'll see that his measurements make perfect sense every single week.

Practical tip: If you're not proficient with Excel or spreadsheets in general, here's a useful tip. You can edit many cells in bulk by selecting the cells/rows/columns you wish to edit all at once, pressing Ctrl + h, typing the text you want to replace and the text you want to replace it with, and clicking 'Replace all'. This allows you to easily change all calculations from the average to the mode. See the image below for an illustration.



The best caliper models

In addition to only looking at skinfold thicknesses directly, taking multiple measurements and normalizing them, it is important to have a good caliper. Most calipers are quite lousy. The table below summarizes the literature on what the best skinfold caliper is. The Harpenden and Lange calipers are the 2 giants that have long served as the industry benchmark of gold standard quality. They are the standard by which other calipers are measured. However, they come with a hefty price tag. The Body Caliper and the Fatometer caliper are almost as good for a fraction of the cost, so for non-professionals, they are arguably the more economical investment. While not validated in research, the old, digital Accumeasure caliper is strongly worth considering. It's relatively cheap like the Fatometer and The Body Caliper and the fact it has an automatic pressure regulator makes it more user-friendly than most manual calipers, thereby significantly reducing the amount of operator skill required for accurate measurements. It's also nicely compact and it conveniently calibrates itself with the click of a button. Menno's experience with clients has been very positive. Unfortunately, the good model is no longer in production. Alternatively, Cescort and Skyndex calipers are also good, but for their price, you may as well go with the Lange or Harpenden calipers. You may be able to find an affordable second-hand pair on eBay.com.

➢ Research overview

[Skinfold caliper brands reliability literature overview]

Here are a few more notes about skinfold calipers.

- Lafayette and Lange will generally overestimate your body fat level, whereas the Slimguide, Harpenden and Skyndex will underestimate it due to lower compression when applied to skin.
- Harpenden calipers will result in slightly lower skinfold thicknesses than Lange calipers by design, so their measurements are not directly comparable, even though both are highly precise.
- Age can change skin compressibility. So calipers may give different values for the elderly compared to the young even when they're at the same body fat percentage.
- Calipers should exert as constant of a pressure as possible throughout the measurement of skinfolds (normally 10 g/mm).
- Calipers should be calibrated regularly for higher accuracy. Accuracy may also decrease as body fat levels increase due to a greater chance of pressure changes throughout jaw opening widths.
- Calibration can be done with foam blocks.

To make it easier for you to start using calipers the right way, here are the starting guides Menno gives to many of his clients on how to use calipers for men and women.

➢ PT Toolkit

How to use calipers [men]

How to use calipers [women]

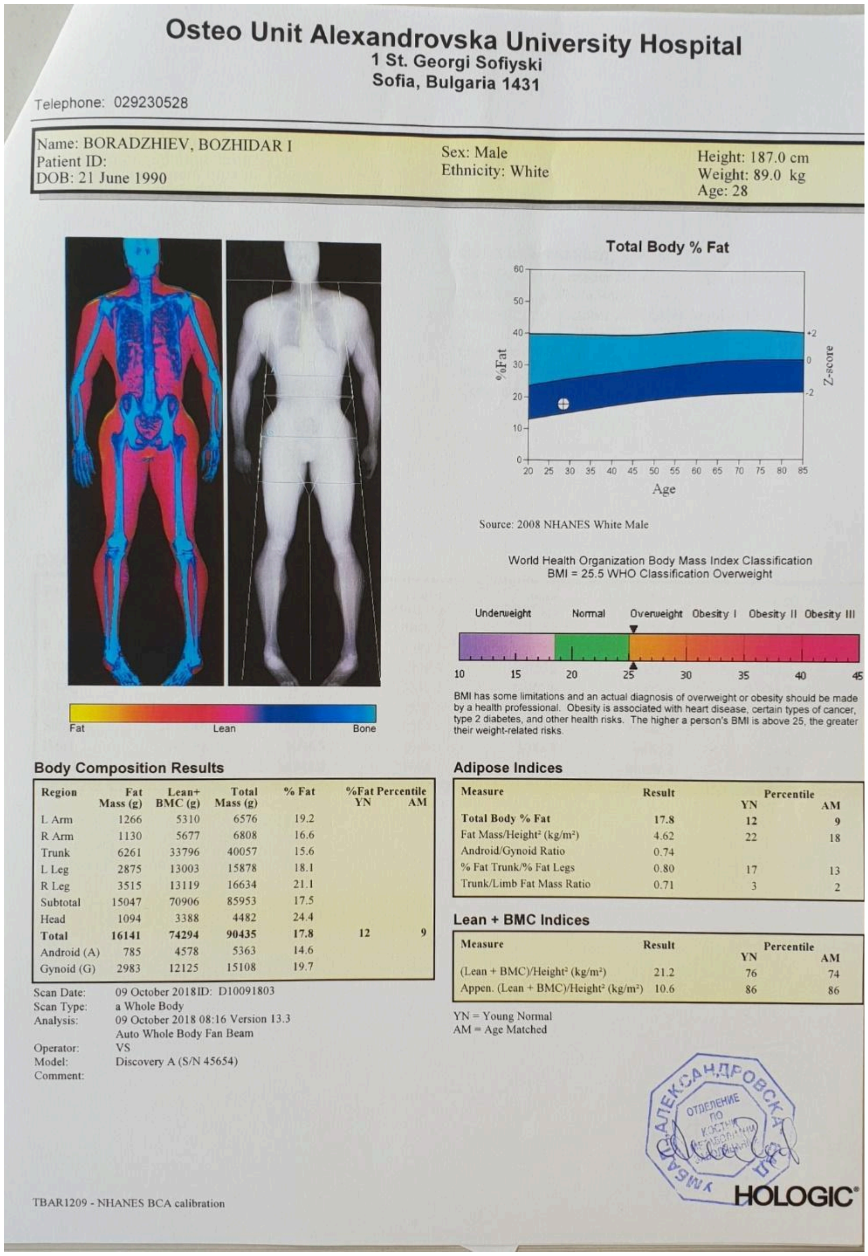
Absorptiometry (incl. DXA)

Absorptiometry is an imaging technique that involves scanning the entire body or a portion of the body with a photon beam. Dual X-ray photon absorptiometry (DXA, formerly DEXA) is the most common type. With the knowledge that different tissues have different densities, DXA scans can be used to estimate 3 compartments of the body's mass: bone mass, non-bone lean body mass and fat mass.

Radiation exposure to subjects is very low, the procedure is relatively quick and the accuracy of the body fat percentage estimate is reasonably high. Of the fancier body fat percentage measurement techniques, DXA is generally the most readily available and affordable with scans costing somewhere around $50.

However, DXA can be influenced by food intake, electrolytes, hydration status, creatine [2, 3] and daily activities, because the scanner cannot differentiate between muscle and fluid mass very well. For example, drinking a large glass of water right before the test will make a DXA scan think you gained that weight in lean body mass, which is technically correct, but it's not what we want to measure. Compared to BIA though, DXA scans are relatively insensitive to changes in hydration status. Working out before a DXA scan, for example, tends to have only small effects on your results. For maximum measurement reliability, you should standardize your measurement conditions [2]. It's generally most reliable to test yourself fasted in the morning. Also, you should compare DXA test results in similar states of energy balance. If you do 1 scan at the end of a bulk and another at the end of a cut, your progression will be confounded by the difference in energy balance. In particular, water retention tends to be considerably higher in energy surplus.

While DXA scan estimates are typically within a few or even one percent of gold-standard multi-compartment body fat percentage estimates and test-retest accuracy is high (ICC > 0.99) [2], they can be wildly off for some athletes [2]. For example, the DXA scan below gave an estimated body fat percentage of 17.8% for someone clearly in bodybuilding contest shape. Unless he had a bulge of fat where his kidneys are supposed to be, that's not very likely. Again though, these are exceptions to what is normally a reasonable estimate of body fat.



Osteo Unit Alexandrovska University Hospital
1 St. Georgi Sofiyski
Sofia, Bulgaria 1431

Telephone: 029230528

Name: BORADZHIEV, BOZHIDAR I
Patient ID:
DOB: 21 June 1990

Sex: Male
Ethnicity: White

Height: 187.0 cm
Weight: 89.0 kg
Age: 28

Source: 2008 NHANES White Male

World Health Organization Body Mass Index Classification
BMI = 25.5 WHO Classification Overweight

BMI has some limitations and an actual diagnosis of overweight or obesity should be made by a health professional. Obesity is associated with heart disease, certain types of cancer, type 2 diabetes, and other health risks. The higher a person's BMI is above 25, the greater their weight-related risks.

Body Composition Results

Region	Fat Mass (g)	Lean+ BMC (g)	Total Mass (g)	% Fat	%Fat Percentile YN	%Fat Percentile AM
L Arm	1266	5310	6576	19.2		
R Arm	1130	5677	6808	16.6		
Trunk	6261	33796	40057	15.6		
L Leg	2875	13003	15878	18.1		
R Leg	3515	13119	16634	21.1		
Subtotal	15047	70906	85953	17.5		
Head	1094	3388	4482	24.4		
Total	**16141**	**74294**	**90435**	**17.8**	**12**	**9**
Android (A)	785	4578	5363	14.6		
Gynoid (G)	2983	12125	15108	19.7		

Scan Date: 09 October 2018ID: D10091803
Scan Type: a Whole Body
Analysis: 09 October 2018 08:16 Version 13.3
Auto Whole Body Fan Beam
Operator: VS
Model: Discovery A (S/N 45654)
Comment:

Adipose Indices

Measure	Result	Percentile YN	Percentile AM
Total Body % Fat	**17.8**	**12**	**9**
Fat Mass/Height² (kg/m²)	4.62	22	18
Android/Gynoid Ratio	0.74		
% Fat Trunk/% Fat Legs	0.80	17	13
Trunk/Limb Fat Mass Ratio	0.71	3	2

Lean + BMC Indices

Measure	Result	Percentile YN	Percentile AM
(Lean + BMC)/Height² (kg/m²)	21.2	76	74
Appen. (Lean + BMC)/Height² (kg/m²)	10.6	86	86

YN = Young Normal
AM = Age Matched

TBAR1209 - NHANES BCA calibration

HOLOGIC

To measure week-to-week progress, DXA scans are not accurate enough, in particular not the segmental analyses such as limb fat-free mass. DXA scan estimates of changes in body composition generally differ by 1-3% and sometimes upward of 5% from 4C-model estimates in bulking strength trainees [2]. That's not bad for group averages, but for an individual measuring short-term progress, the error margin is often as large as the actual change in body composition values. DXA scans are thus considerably worse than properly used skinfold calipers or tape measures to track someone's progress. This actually goes for all commercially available body composition testing methods: none are accurate enough to reliably track changes of only a few percent in strength trainees' body composition.

Thus, is it worth getting a DXA scan? Probably not. In practice, DXA scans could be useful to get a starting estimate of someone's body fat percentage or as a very long-term measure of body composition progress, similar to multi-frequency BIA scans. However, the practical utility of the scan information is generally slim compared to a good visual estimate and the scans are too unreliable to measure progress on a weekly or even monthly basis.

Bioelectrical impedance analysis

Bioelectrical impedance analysis (BIA) is a commonly used method to estimate someone's body composition by running an electrical current through the body via electrodes that pass from foot to foot, hand to foot or hand to hand. The most common examples of BIA are the digital body fat scales you can stand on, sometimes with hand grips, like those from Tanita. By sending an electrical current through the body via the feet, the hands, or both, the device measures the opposition to the current – impedance. The lowest impedance value can be used to predict fat-free mass, because your organs, muscles and blood all have a high amount of water and electrolytes that easily conduct the current. Adipose tissue, your fat mass, has a poorer electrical conductivity. So with some math, BIA allows us to estimate someone's body fat percentage. BIA is very safe and rapidly becoming more popular because of its ease of use and non-invasiveness.

A BIA scanner (InBody model).

While older single-frequency BIA scans could only distinguish between lean and non-lean tissue with impractically poor accuracy, newer multi-frequency BIA methods can also estimate body water and bone and thereby divide the body into 3 or 4 compartments rather than 2, greatly increasing their accuracy. When multiple frequencies are used, the higher frequencies can estimate both intracellular and extracellular water, because the higher-frequency current can penetrate cell membranes. Low frequencies cannot pass cell membranes, so they primarily measure the presence of extracellular water.

Of the commercially available body composition techniques, multi-frequency BIA measurements can come close to gold-standard 4C techniques to measure body composition in bodybuilders and can in some cases even be slightly more reliable than DXA scans, though other research finds multi-frequency BIA scans, including the InBody, significantly deviate from DXA scans in lean, athletic populations [2, 3]. Single-frequency BIA does not correspond well with DXA scans at all [2]. Most 3C and

4C body fat percentage estimates are accurate within 2%, but 5% error in either direction occurs in some scans.

Unfortunately, many 3C or 4C methods for BIA and BIS scans require an adjunct measure of body volume or body water, which requires methods typically restricted to laboratories. Most commercially available body fat scales are single-frequency, so they have poor accuracy. They're also generally not calibrated for muscular individuals. BIA scales without hand grips are particularly unreliable generally [2, 3]. You need a device that sends the electrical current through both your hands and feet for reasonable accuracy. The best commonly available multi-frequency BIA scanner is currently arguably the InBody. Although it's only a 2C model, the InBody has been found to estimate body fat percentage within a few percent accuracy of 4C models in untrained individuals [2]. In trained populations, most research finds significant discrepancies between InBody and DXA scan results [2, 3, 4], though some research finds reasonable agreement between multi-frequency BIA and 4C models, as well as DXA scans.

Regardless of device, the appendicular estimates of fat-free mass or body fat are too unreliable for practical use [2], and weekly or even monthly changes are generally too variable or insensitive to be used to measure progress over time.

Even the best scales suffer from one major, inevitable problem inherent to BIA: the measurement is strongly affected by hydration status. If you're dehydrated or bloated, the scale will tell you your body fat percentage has changed when of course it has not. So you'll get different readings before and after going to the gym as a result of the loss of electrolytes and sweat and you'll get different readings before and after having a drink [2]. To account for this, it is best to perform the measurements fasted and after having gone to the bathroom.

In practice, BIA is not very useful, unless you happen to have access to 3C or 4C methods multiple times per week, fasted in the morning. Single-frequency BIA scans are practically useless. Commercial multi-frequency BIA scanners like the InBody can be used to roughly estimate your body fat percentage to calculate your starting macros for a program, but BIA measurements are generally too unreliable to monitor weekly changes in body composition. Skinfold calipers and circumference measurements are better for week-to-week progress measurements.

A method very similar to BIA is bioimpedance spectroscopy (BIS). They only differ in how they mathematically calculate body fat percentage based on the impedance measurements.

Electrical impedance myography (EIM), a method most commonly used by the Skulpt to estimate body fat percentage, is also similar to multi-frequency BIA in terms of accuracy at measuring body composition. It correlates only moderately well with DXA scans even in untrained individuals and there's no research on trained individuals.

There are many more laboratory based techniques to estimate your body fat percentage, but they're generally not commercially available, so we won't go into those here. As a rule of thumb if you're interested in reading research though, it's useful to know that the number of compartments a model has corresponds well to its accuracy. The gold standard is 4C models.

Body composition tracking for women

It is often said that the body composition of women and in particular their water retention fluctuates dramatically over the menstrual cycle to the extent that body composition cannot be compared week to week and rather should be compared month to month in each phase of the menstrual cycle. Well controlled research shows that body composition, including hydration status, is actually quite constant across the menstrual cycle [2]. Skinfold calipers, DXA scans and ultrasound body fat estimates are consistent across each phase of the menstrual cycle in physically active women. So body composition changes can generally be measured in the same way in men and women: measures like bodyweight and skinfold thicknesses can still be accurately tracked on a week to week basis. BIA readings seem to be more affected but you should normally still see the weekly average BF% go down during a cut.

Body composition tracking conclusions

It's generally not worth getting expensive body composition testing done. Of the commercially available methods, DXA and InBody scans may give you a decent estimate of your body fat percentage, but the estimate may not be better than an experienced visual estimate. No body composition testing method is accurate enough to reliably detect the small changes in body composition that typically happen in strength trainees over the course of a week; when bulking, nothing is very accurate even over a 6-week program, except maybe in novices or trainees on anabolics. Instead of trying to track your exact body fat percentage, you're generally much better off properly using high-quality skinfold calipers or even just a tape measure combined with daily, standardized weigh-ins to measure your week-to-week progression. Be flexible with how you conduct the measurements. There is no one-size-fits-all method. Rather, consistency is everything. You may have to track medians or modes of your skinfold measurements or different locations.