MENNO HENSELMANS
Science to master your physique

# NUTRIENT TIMING:

## FASTING & OUR BIORHYTHM

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# Contents

## ➢ Lecture

Fasting and biorhythm effects [slides]

Traditional bodybuilding wisdom is that you have to eat 6 meals a day on the clock to fuel around-the-clock anabolism. Not eating breakfast means leaving gains on the table. Conventional wisdom also says breakfast is the most important meal of the day. Because of the hefty consensus in favor of breakfast eating, anyone not eating an early morning breakfast was often ridiculed in bodybuilding circles.

This changed several years ago when Swedish bodybuilding coach Martin Berkhan started popularizing ‘intermittent fasting’ (IF). Martin’s ripped physique, his scientific critique of having to eat 6 meals a day and his client before-afters convinced many people to try his LeanGains approach with 16 hours of fasting a day and an 8 hour eating window. IF quickly became very popular among the Reddit, Misc and other open-minded crowds. The results were good and by comparison to having to eat 6 meals every day on the clock, IF felt like heaven as a lifestyle. When the HodgeTwins and some celebrities jumped on the bandwagon and if-it-fits-your-macros became popular, not only had IF become fashionable, many people, especially in the if-it-fits-your-macros (IIFYM) culture, had become skeptical of the whole concept of nutrient timing, thinking it doesn’t matter when you consume what, as long as you hit your daily macros. If you think about it, this is ironic, because the very concept of daily macros implies that nutrient timing matters: you have to consume the nutrients within a 24-hour window that happens to coincide with Earth spinning around its axis.

Moreover, it can easily be deduced *a priori* that nutrient timing matters. If we compare 2 groups of people with one group eating all of their weekly macros on Saturday and the other group spreading their meals out across the week as most people do, is there really anyone who believes the person eating only on a single day of the week will gain as much muscle as the person eating every day?

So there really is no logical debate necessary about whether nutrient timing matters. It matters. What we'll focus on in this topic is how much it matters and within which time frames.

But before we turn to nutrition, let's talk about your biorhythm and how this relates to training, because it doesn't just matter when you eat: it also matters when you train.

# Circadian rhythm training timing

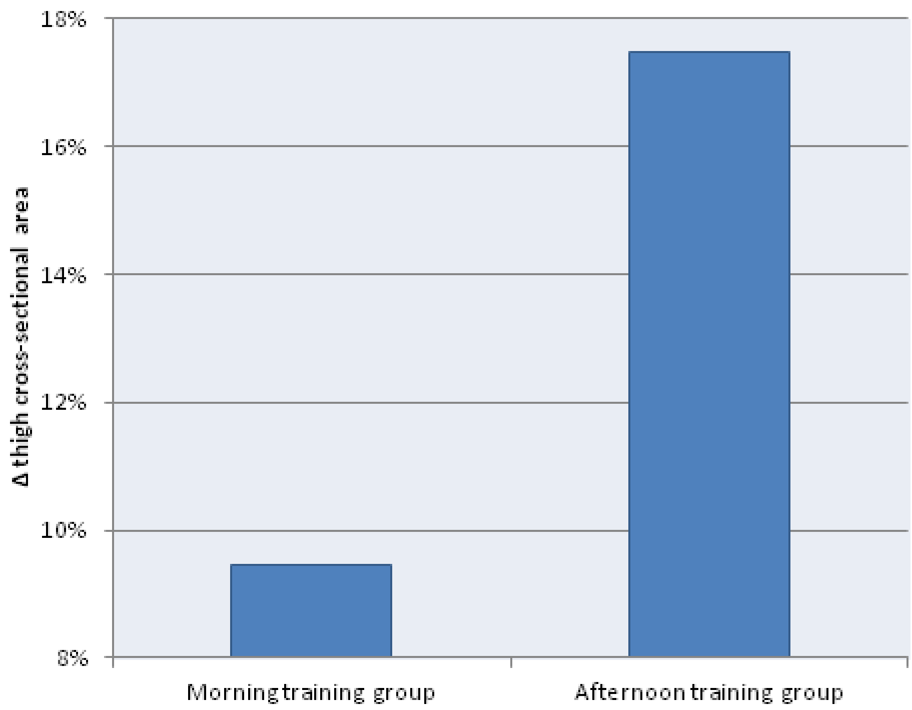
The optimal time of day to train is not usually something that people think about, yet there is a science to optimizing your training times. By carefully orchestrating your training schedule in accordance with your circadian rhythm, you will be stronger, faster and more powerful. After the training, you will recover better and gain more muscle.

Sounds too good to be true? Several studies have looked at long term muscle size and strength gains in groups training at different times of day. Even when people are consistent with their training times, strength increases are generally slightly higher and muscle gains up to 84% higher have been found when training in the evening instead of the morning.

## The data

Küüsmaa et al. (2016) studied the effectiveness of a training program performed in the morning between 06:30 to 10:00 h or in the evening between 16:30 to 20:00 h for a 24-week period. While strength and endurance performance improved similarly across the groups, the men training in the evening gained significantly more muscle mass from the midpoint of the study onward (quadriceps CSA).

Laczo et al. also presented the following data at the 7th International Conference on Strength Training in 2010.




[Malhotra et al. (2014)](#) studied how training in the morning vs. the evening affected strength development. Strength gains were significantly greater in the evening for eccentric exercise: 29% vs. 23%. For concentric training, the difference was trivial with 23% vs. 21%.

Tim Scheett performed a study in bodybuilders on the best time to work out. Half of the participants trained before 10 AM in the morning, the other half after 6 PM in the evening. While the results never got published outside of the 2005 NSCA conference and didn't reach statistical significance because of having only 16 participants in the study, look at the data below: the evening training group had much more favorable body composition changes.

| | Fat-free mass | | Percentage fat | |
|---|---|---|---|---|
| AM group | +0.6% | | +5% | |
| PM group | +3.2% | | -4% | |

Sedliak et al. (2009) studied trained men working out around either 8 AM in the morning or 6 PM in the evening. While again there were no statistically significant changes in strength development or muscle growth, muscle growth was 3.5% in the evening group vs. 2.7% in the morning group. Statistical power was low considering there were only 7 and 9 men in the training groups and the study only lasted 10 weeks.

Brooker et al. (2019) also found tentative support for greater gains when training in the evening instead of the morning in previously untrained individuals. The study didn't perform statistical analyses because they only had 9 and 7 participants in the morning and evening training groups, but after 12 weeks, the evening training group achieved slightly better body composition changes: see the table below.

| | AM | | PM | | % change | |
|---|---|---|---|---|---|---|
| | PRE | POST | PRE | POST | AM | PM |
| Waist circumference (cm) | 95.2 | 89.5 | 105.5 | 97.7 | -6% | -7% |
| Fat mass (kg) | 36.1 | 34.6 | 38.8 | 36.9 | -4% | -5% |
| Lean mass (kg) | 48.4 | 47.6 | 48.3 | 48.2 | -2% | 0% |

Küüsmaa-Schildt et al. (2019) compared combined strength-endurance training in the evening or morning in untrained, young men over a 24-week study. While the between-group difference in strength development did not reach statistical significance due to major interindividual variation, the evening group achieved greater leg press strength gains in the evening (14% vs. 10%) as well as in the morning (16% vs. 10%) than the morning training group. Moreover, evening strength development was only statistically significant in the evening training group, not the morning group. (Unfortunately, no other strength or body composition data were reported.) Sleep quality was unaffected by training time.

Mancilla et al. (2020) compared combined strength-endurance training in the morning vs. afternoon in untrained, not-so-healthy individuals. The training programs involved 3 sets of 10 at 60% of MVC, so they were not very effective to increase maximal strength or fat-free mass, and unsurprisingly then, the gains didn't differ between groups. However, maximal power output increased more in the afternoon training group. Interestingly, the afternoon training group also lost significantly more fat and experienced greater improvements in insulin sensitivity and blood sugar control.

In contrast to the trends in the above studies, multiple other studies have not found any differences in training outcomes as a result of different training times.

Sedliak et al. (2018) found similar anabolic signaling, hormonal effects, muscle growth and strength development in untrained men over the course of a training program performed either in the morning or the afternoon. However, with only 7 and 11 subjects in the 2 groups, this study was statistically underpowered to detect even a medium effect size. They couldn't even find significant correlations between the different measures of muscle growth, so if there were benefits of training in the afternoon, as the other research suggests, they may well have been masked by the large variation in the data and this study wasn't powered enough to detect it. Plus, the former study by these researchers only detected the effect after week 11, but this study was only 11 weeks in duration.

Krčmárová et al. (2018) found no significant difference in strength development, body recomposition or functional capacity tests between 2 groups of previously untrained 60+ year-old elderly women that trained in the morning or evening. Interestingly, the evening group did experience better health improvements with significantly greater decreases in blood sugar and triglyceride levels. Other biochemical and inflammatory markers did not differ between groups. Looking at the absolute changes between groups, the evening group lost more fat and had better health improvements, whereas the morning group experienced greater muscle growth and strength development. This difference suggests the evening group consumed fewer calories. There was no diet control, so a difference in macronutrient intakes between groups is plausible.

The researchers had a different explanation though for the lack of results, in contrast to previous research: elderly individuals have blunted and advanced circadian rhythms compared to younger individuals (discussed later). As such, the time at which you train may not matter as much for the elderly. In fact, some research has found that elderly individuals are more fatigued later in the day and experience higher perceived exertion during exercise compared to the morning when they're still fresh and fruity. The training program consisted of whole-body training to muscle failure. So grandma may have been a bit reluctant to go balls-out during her leg presses when it was time for her nap.

A 2019 meta-analysis tried to see if the literature as a whole supported benefits to training in the evening. Unfortunately, Laczo's and Scheett's studies were never published, so they didn't make it into the analysis and Brooke's study wasn't published at the time yet. The meta-analysis also included an irrelevant study on pre-pubertal boys by Souissi et al. (2012) in which neither group gained any lean body mass. The meta-analysis concluded people are on average stronger in the evening than in the morning, but strength and muscle development are similar when training consistently at that time. However, a closer look at the data suggests strength gains were time-of-day specific and muscle growth in the only relevant 3 studies favored evening workouts.

A 2023 meta-analysis by Brugisser et al. similarly concluded that training at a consistent time seems to be better for performance, but they found no strong evidence that training at any specific time of day resulted in better gains. Unfortunately, performance was only measured as endurance or sports performance, not muscle strength (e.g. 1RM). And the authors only included the 2 Sedliak et al. studies on muscle hypertrophy. It's unclear why Küüsmaa et al. (2016), which significantly favored evening workouts for muscle growth, was not included.

Arciero et al. (2022) found variable effects of training in the mornings (AM) vs evenings (PM). In women, the PM group gained significantly more bench press and push-up strength, yet the AM group lost more fat, despite similar self-reported energy intakes. In men, the time of day they trained did not affect their performance improvements or body recomposition.

## Summary

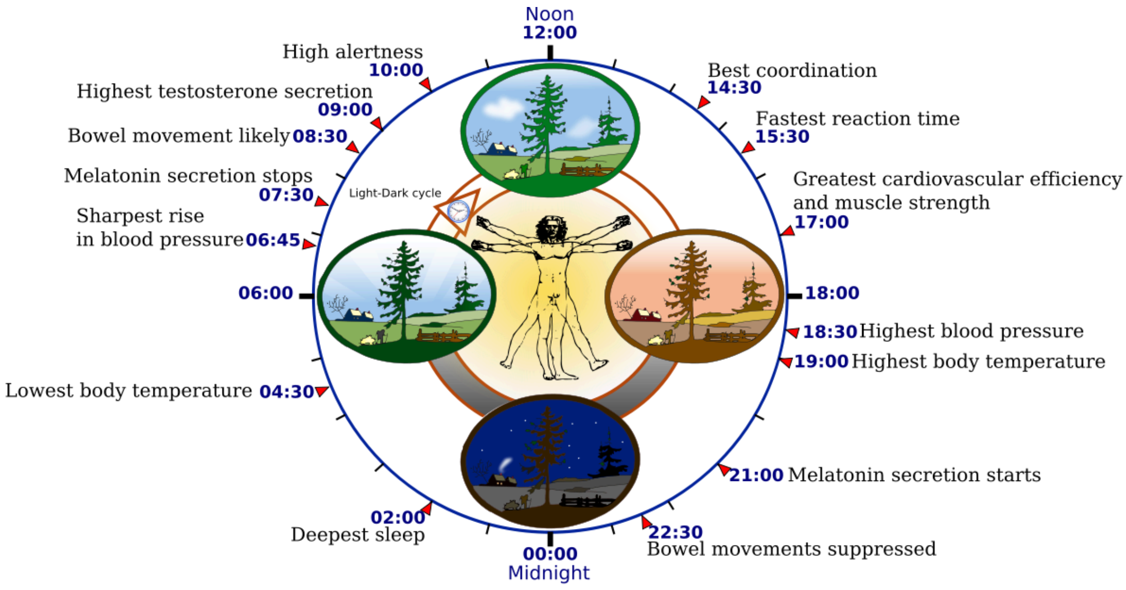
While findings are mixed and plagued by low statistical power, the overall trend of the research suggests it's slightly better to exercise in the afternoon or evening instead of the morning. Personal preference and scheduling convenience may make the consideration moot for recreational trainees though. It's of course much more important to get your workout in in the first place than when you do it.

Why would the time of day affect how much muscle you gain after a workout? It's because of your circadian rhythm.

## Circadian rhythm 101

Your circadian (sir-kay-dee-an) rhythm is a daily cycle of biological activity. The biological activity with the most obvious circadian rhythm is your sleep-wake cycle. Think of your body as having an internal clock that regulates when to activate every system. In fact, [the part of your brain called the suprachiasmatic nucleus (SCN) has built-in molecular oscillators that function very much like a pacemaker with an average cycle of 24 hours and 15 minutes], almost exactly a day. That's why the SCN is also called your internal or biological clock.

The SCN interacts with virtually every major system in your body, including hormone production and central nervous system activity, which each have their own peripheral clocks that listen to the master clock. Your biological clock quite literally tells all the systems in your body what time it is. This influences when they become more active and how they function. Look at the image below for examples of biochemical and physiological events with a 24-hour biorhythm for a person with a standard lifestyle in a Western society.



Your SCN influences when which system becomes active in your body, but you do too, as you determine when you eat, sleep, see daylight, etc. So for your body to function optimally, your biological clock needs to be aligned with your lifestyle. As you've probably experienced, if you want to sleep when it's not bedtime yet according to your biological clock, it's hard to fall asleep and your sleep quality is not as good as otherwise. So eating at irregular times can result in suboptimal metabolic effects, as we'll discuss later. An extreme example of chrono-disruption is jetlag. When we travel to a different time zone, our lifestyle becomes desynchronized from our internal clock, causing all our bodily systems to malfunction to an extent. This can result in not being able to sleep, nausea, mental fogginess, lethargy, hunger pangs or lack of hunger and many more symptoms.

To synchronize your biological clock with your lifestyle, your SCN responds to 'zeitgebers', which is German for 'time givers', that 'entrain' your biological clock. In other words, these zeitgebers tell your biological clock what time it is so it can in turn inform the peripheral clocks. Peripheral clocks can in some cases maintain an independent circadian rhythm though.

The most important zeitgeber is light. Your SCN is closely connected with your retina. The SCN uses the intensity of light to determine where you are in your sleep-wake cycle.

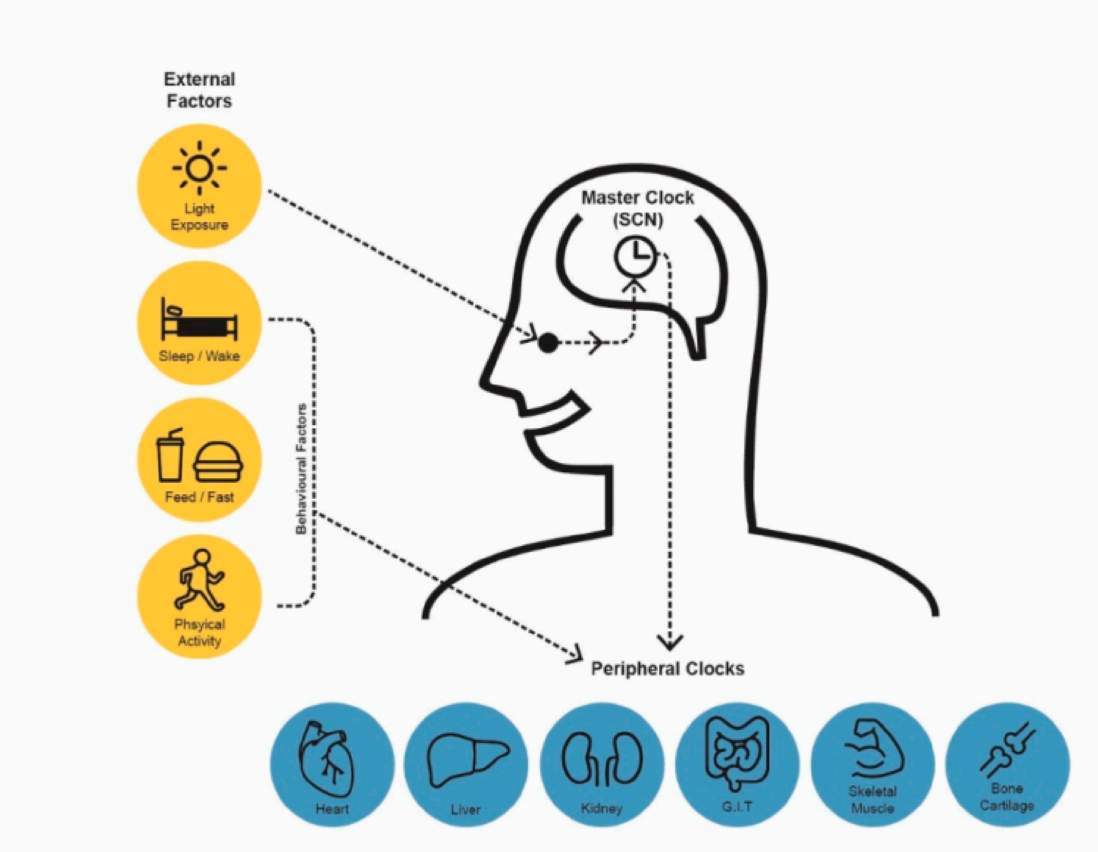



**Figure 1.** Human Circadian System: Comprised of a central clock and peripheral clocks. The central clock located in the hypothalamus is entrained by light. Peripheral clocks are influenced by physiological/behavioural factors such as sleeping and eating. Synchonisation of peripheral clocks, under the orchestration of the central clock, is essential to achieve circadian alignment.

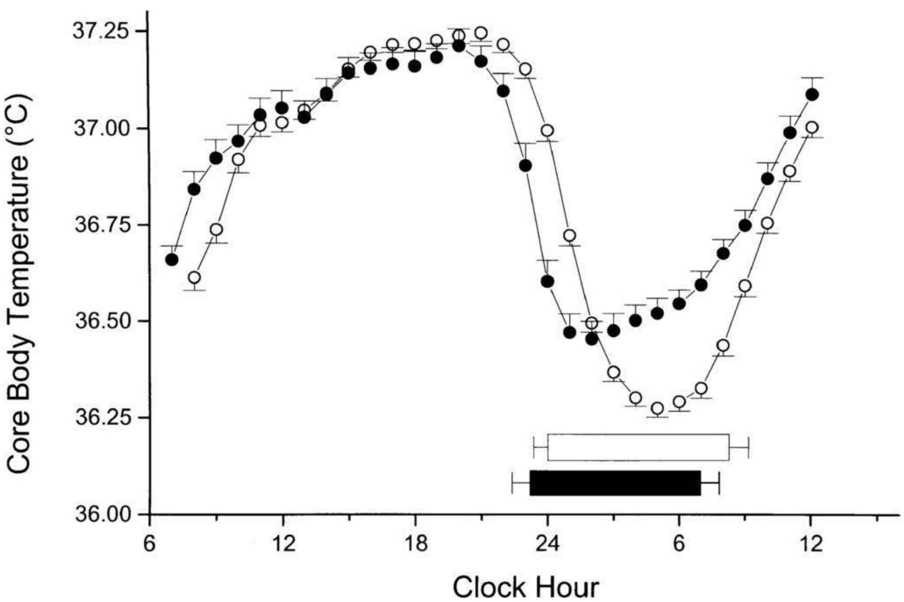
Source

For athletes, systematic daily variations in core body temperature, energy metabolism and hormonal milieu may influence the results of training at a certain time of day. The strongest determinant of performance seems to be our core body temperature.

## Core body temperature

Core body temperature is the temperature at which your central organs operate. Enzymatic reactions are extremely sensitive to minor variations in your core body temperature. For the biological systems involved in high intensity physical exercise, the optimal temperature is relatively high. High core body temperatures improve nerve conduction velocity, joint mobility, glucose metabolism and muscular blood flow. Most people can achieve higher muscle activation levels in the evening compared to the morning. As a result, core body temperature correlates with exercise performance. People are normally strongest when their core body temperature reaches its daily peak.

Core body temperature is low at night, rises quickly upon awakening and reaches a maximum in the evening: see the graph below.



For the older readers, peak performance for strength training in middle aged adults occurs earlier than in adolescents. In the temperature graph above, the black dots represent older subjects.

The optimal body temperature for strength training normally occurs in the late afternoon to early evening [2, 3, 4]. That's when flexibility, power and muscular strength reach their daily peak.

Accordingly, most sports records are broken in the early evening.

The peak performance time (acrophase) differs per activity. For example, swimming performance peaks a few hours later in the evening than most ground based activities. In general, endurance capacity seems to have a less pronounced circadian rhythm [2]. See the table below for an overview of the peak performance time for various studied performance measures.

The effect of time of day on short-term exercises.

| Refs | Participants | Age (y) | Measurement parameters | Acrophase | Amplitude |
|---|---|---|---|---|---|
| Atkinson et al69 | Trained (*n* = 7)<br>Untrained (*n* = 7) | 19–29<br>Trained, 23.9 ± 3.3<br>Untrained, 24.3 ± 24 | Whole-body flexibility<br>Back and leg strength<br>Grip strength<br>Flight time in a vertical jump<br>Self-chosen work rate | 17:00–19:00 h | Trained > untrained<br>(˜ 2–10% vs. ˜ 1–7%) |
| Wyse et al70 | 9 Collegiate sportsmen | 19.6 ± 9.6 | Extension peak torque<br>Flexion peak torque | 18.00–19.30 h | ˜ 5–12% |
| Gauthier et al52 | 13 Physical education participants | M: 22.0 ± : 22.0<br>physical education | Elbow flexor torque | 18:00 h | ˜ 4% |
| Martin et al71 | 13 Healthy participants<br>(12 M and 1 F) | 22–40 | MVC | 18:00 h | 8.9% |
| Callared et al72 | 6 M<br>ultradistance cyclists | 33.4 ± 3.4 | MVC | 19:30 h | 6% |
| Souissi et al73 | 13 M physical education students | 22.4 ± 2.4 | Maximal power during the force velocity test | 18:00 h | 8.3% |
| Castaingts et al74 | 11 M | 18–30 | MVC | 18:00 h | 8.6% |

F, female; M, male; MVC, maximal voluntary contraction; NS, not significant.

*Source*

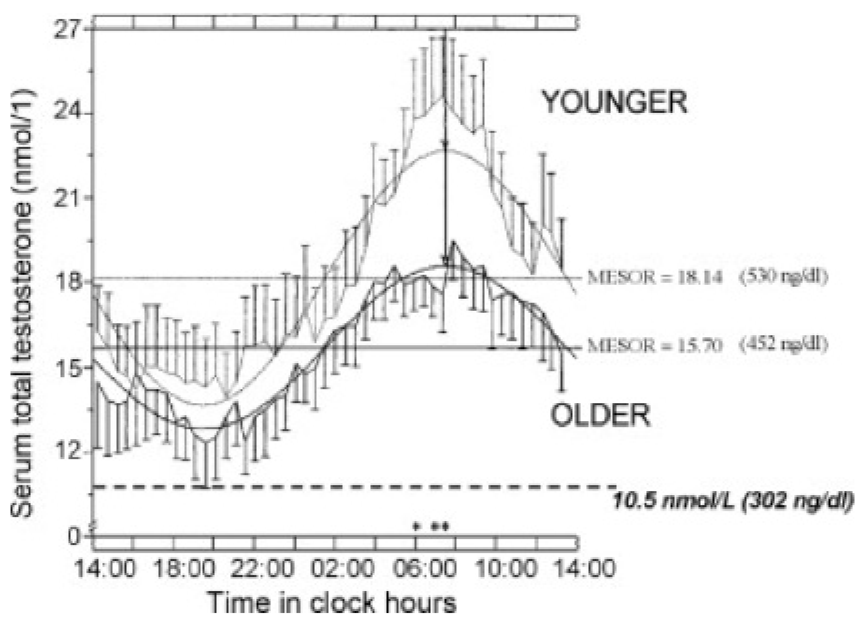
Greater performance can obviously lead to greater muscular adaptations, as you can impose more mechanical tension on the muscle fibers to stimulate them to grow and you may reach higher levels of muscle activation to enhance neural efficiency (see course module on understanding muscle growth).

Daily variations in hormone levels may also influence our gains. Let's look at testosterone, the 'alpha hormone', and cortisol, the 'stress hormone'.

## The T/C ratio

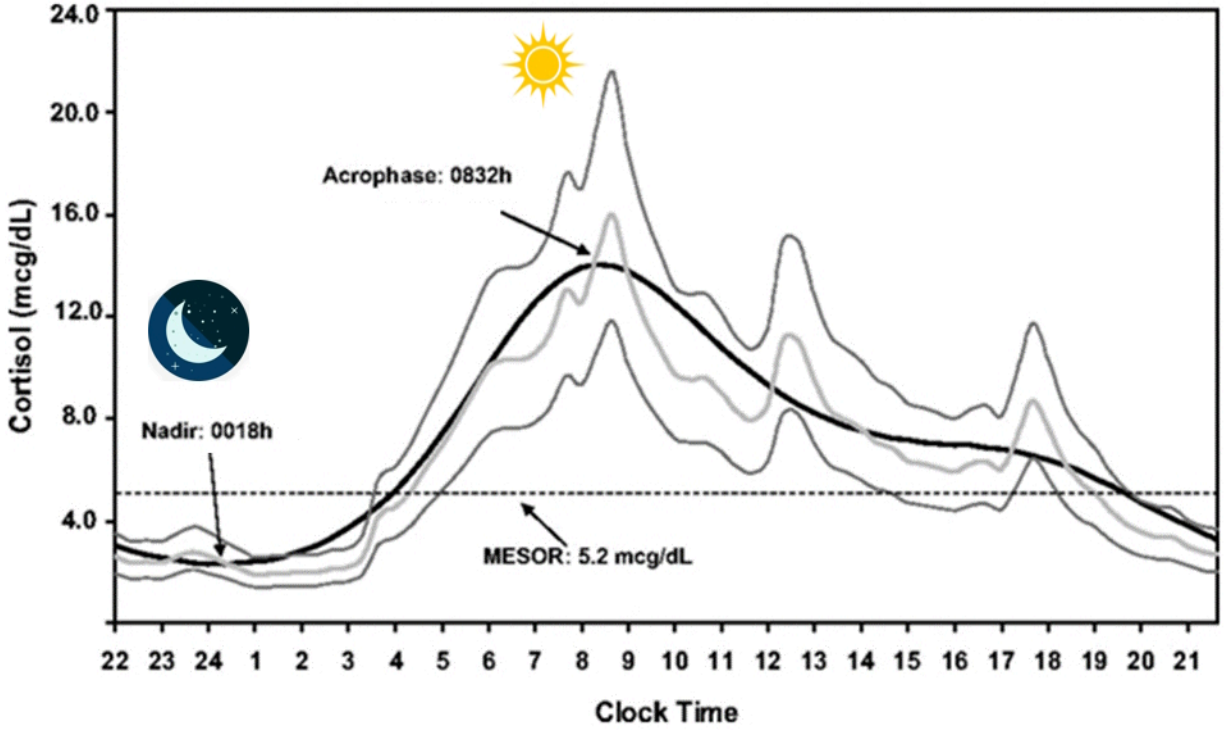
It's common knowledge that high testosterone levels are anabolic and thus beneficial for muscle growth and strength development, whereas cortisol has catabolic effects and excess levels can be detrimental. Accordingly, the testosterone to cortisol ratio or the T/C ratio is commonly used as a marker of tissue anabolism and a measure of overtraining. Although its use for both is contentious, it might be beneficial to train at a time of day when the T/C ratio is highest.

Testosterone production rises in the evening, peaks very early in the morning and then decreases across the day: see the graph below. Tangentially, testosterone's strong biorhythm is the reason testosterone bloodwork should always be done in the morning (fasted) to get comparable results.




*The biorhythm of testosterone.* [Source]

[Cortisol output is low at night, rapidly rises during awakening and then gradually decreases over the course of the day]. In the morning, [a sharp rise in cortisol is associated with the transition from the sleep- to the wake-cycle and bright light exposure amplifies the morning cortisol spike and alertness]. Throughout the day, [cortisol is thought to be a reason you have more symptoms of illness in the evenings than in the mornings for certain illnesses]: cortisol suppresses many of the symptoms in the morning. At night, cortisol levels should be very low. If they're not, that makes it difficult to fall asleep.




*The biorthythm of cortisol. Adapted from [source](source).*

As you can extrapolate from the above graphs, the T/C ratio is highest in the afternoon and evening [2, 3]. Moreover, during this period, exercise causes the smallest rise in cortisol and the largest increase in testosterone [2].

It's plausible that the hormonal milieu in the late afternoon is optimal for maximum muscle anabolism. However, as we'll discuss in the topic on understanding muscle growth, the research is still contentious about the role of endogenous hormonal elevations for muscle growth. The magnitude of the hormonal fluctuations may not be enough to cause significant effects on muscle growth and their role may be unrelated to muscle growth in the first place.

## Intracellular myogenic factors

Core body temperature and hormone levels are systemic. They affect the entire body. In addition to their biorhythms and the regulation of the central block (SCN), the biorhythm of your muscles' activity is also regulated by peripheral clocks residing in each muscle cell. Each muscle cell has its own peripheral mini-clock that regulates its activity, including that of anabolic processes. Specifically, myogenic determination factor 1 (MyoD) is a transcription factor involved in the regulation of satellite cell activation and muscle growth. Intramuscular interleukin-6 (IL-6) production, which you learned about in the section on the relation between inflammation and muscle growth, is also under the influence of the muscle cell clock. These and other factors create a biorhythm of myogenic expression. This may affect how much muscle growth you experience when training at a certain time of day. Some research finds muscle anabolic signaling after a workout can be stronger in the afternoon than in the morning. However, other research finds the signaling may simply be different but not necessarily better in the evening [2], so it's unclear how the biorhythm of intracellular myogenic factors influences our gains.

Regardless of which mechanisms are responsible, peak performance and exercise adaptations correlate strongly, so you should ideally train when you personally perform best [2]. We have a lot of research on this.

## The best time to work out

The best time to schedule your training sessions for peak performance is between 14:30 and 20:30 h if you have a normal biorhythm and sleep during the night from roughly 12:00 – 08:00 h.

For those with an irregular sleep-wake cycle (we're looking at you, college students), it's preferable to wait at least 6 hours after awakening before training. The optimal training time will then be closer to 20:30 h than 14:30 h.

However, different people can have a significantly different biorhythm and 'chronotype'. This individual variability in chronotype probably explains why the research isn't very consistent. People differ in their chronotype: some people are true 'early birds' and they show far less loss of performance in the morning than typical 'night owls'. People also vary in the extent to which they can adapt to morning training. So some people can do just fine training in the early morning.

Beware that your biological chronotype is not the same as if you identify yourself as a morning person. The time at which you *feel* best is mostly influenced by what you're used to. If you've been waking up and training at 6 AM the past several years and you're exhausted by 8 PM at night, you may identify yourself as a morning person now, but if you shift your schedule around and start sleeping in late, a week or two later you may feel better at night. Likewise, many college students can't fathom the idea of getting up early and hitting the gym, but once they're forced to do so when they start an office job, they do much better than they expected. Mule et al. (2019) found someone's chronotype predicts RPE values during exercise but not objective performance. So it's best to rely primarily on objective performance data, not how you feel. That's a good life lesson in general: trust facts over feelings.

When experimenting with at what time your performance is optimal, you can use your heart rate as a guideline, although this level of analysis is probably overkill for most trainees. Resting heart rate and core body temperature are strongly correlated. Therefore, the time of day when your resting heart rate peaks is often the best time to train. Unfortunately, simple oral or insulated axilla (under the armpit) temperature readings are too noisy to measure your circadian rhythm [2]. The scientific gold standard is sticking a thermometer up your ass, but that's probably reserved for the real die-hards. As some researchers put it, "Core temperature is often measured using a rectal probe, a thermistor inserted 10 to 12 cm [4 to 5 inches] past the anal sphincter. Participants are not always comfortable with this site […]".

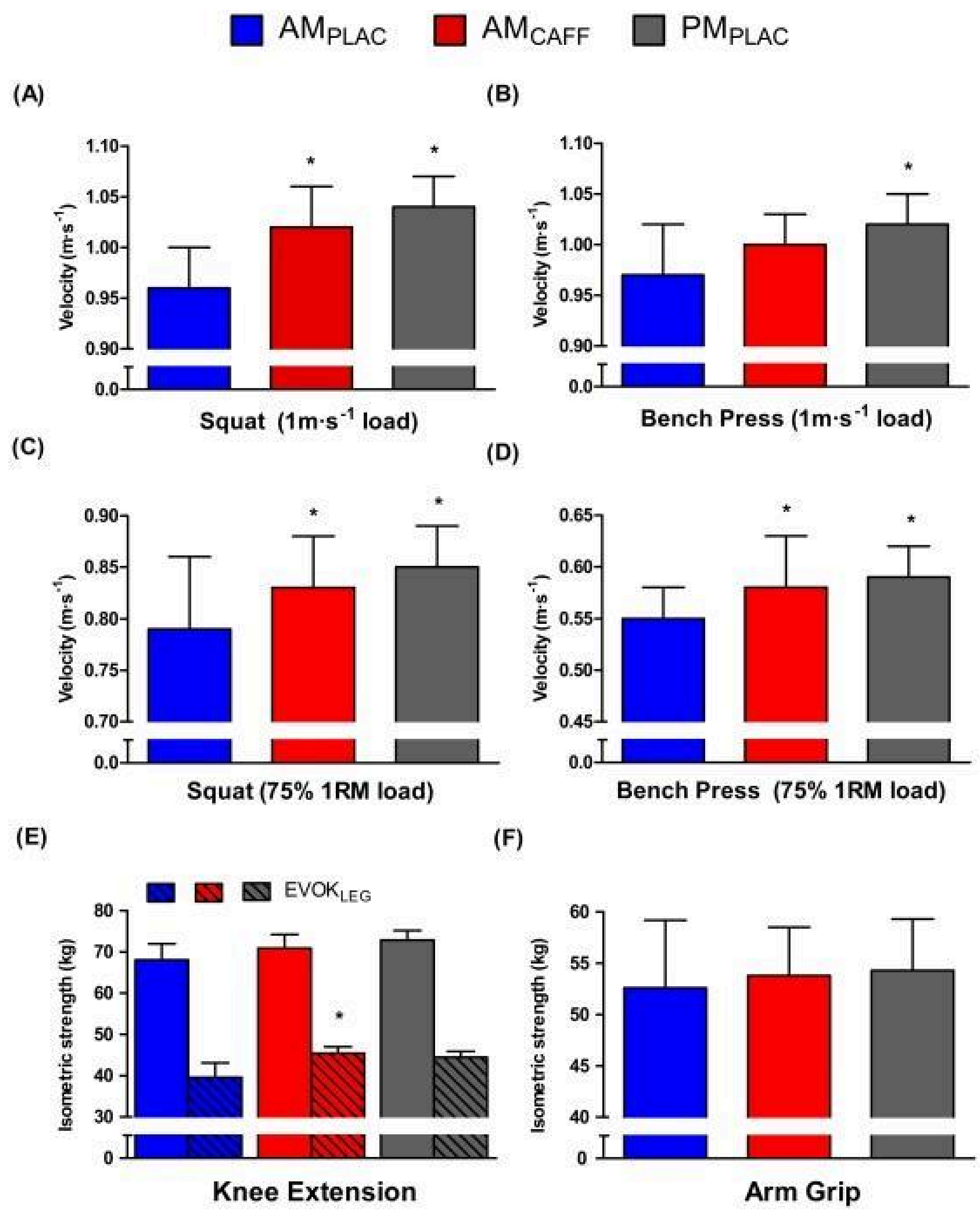
## What if you can't train at the optimal time?

Not everyone has time to train at the physiologically optimal time. However, for most people this is just an excuse. "Not having time" to train actually means "I value training less than the thing I'll do instead". The things you make time for are the things you prioritize. In Dutch, the word for priority is pronounced as the Dutch equivalent of 'prioritime'. Time equals priority.

That said, it's certainly a reality that not everyone has the luxury of planning their training sessions during the physiologically optimal times. Jobs, kids, family, life can get in the way. So what's a lifter with a genuine scheduling problem to do? There are 2 strategies you can employ.

### Strategy 1: Caffeine

Caffeine effectively forces your body into daytime mode. That's why it helps counteract sleep deprivation so effectively. A dose of ~250 mg (3 mg/kg) caffeine in the morning raises neuromuscular readiness to perform close to afternoon levels. As you can see in the graph below, there was still a trend for lower performance in The AM + caffeine group compared to the PM group, even though the PM group didn't consume caffeine, but this difference was not statistically significant. This may well have been due to the small sample (N = 12) and resulting [insufficient statistical power to detect the performance decrement](#).



There are several reasons why taking caffeine in the morning as a pre-workout may not be 100% optimal.

- Caffeine decreases the T/C ratio.
- Caffeine doesn't elevate morning growth hormone levels to afternoon levels.
- Caffeine can interfere with your sleep.
- Most importantly, if you consume more ~100 mg of caffeine daily, you'll develop a tolerance to caffeine's ergogenic effects (discussed in the topic on supplements). So you'll need to save up caffeine from other days generally to be able to use it before morning workouts.

Overall though, caffeine use, especially over 3 mg/kg, when training in the morning will give most people results that are practically equal to evening workouts.

## Strategy 2: Consistency

The second strategy to increase your performance when training at a suboptimal training time is to make sure you always train at that time. Your body will adapt its circadian rhythm to the morning training stress and reduce the performance decrements at that time [1, 2].

However, it seems your biorhythm cannot perfectly adapt to training in the early morning to the extent that performance is 100% unaffected compared to training later in the day. The nervous system adapts reasonably well, but physiological systems such as hormone production adapt less well. This corresponds with the trend in research that muscle growth is more strongly affected by training in the morning than strength development is.

Your body also acclimates to training in the early evening by increasing the circadian variation in performance throughout the day. As such, it is still best to train when your body is biologically primed to do so, because you'll prime it even further to train at this time.

However, with meticulous circadian rhythm control using supplementation, light therapy and consistent nutrition and training (discussed in the lifestyle topic of the course), you can shift your optimal training time greatly and you can achieve comparable results when training in the morning compared to training later in the day.

Shift workers and people with an irregular lifestyle will sometimes have to drastically alter their daily schedules. In these scenarios, remember that consistency is everything. For example, night shift workers can have an optimized biorhythm if they consistently sleep during the daytime, train 6-13 hours after awakening and eat their meals at regular times spread across the day/night. It's the relative times, not the absolute times, that matter. So the key with uncommon schedules is to find times, whenever they are, when someone can sleep, train and eat consistently. If no such times exist at all, which is quite rare, compromises have to be made. If the times shift because someone's shift hours change, the schedule will have to aggressively change along with the change in work hours to have to biorhythm adapt, exactly as if someone had flown to a country with a very different time zone.

If you really can't optimize your schedule in any way, remember that training in the first place is always much more important than *when* you train. If your schedule prevents you from training in the afternoon, getting in your workouts whenever you can, is priority number one. If you're a natural morning person, this may work perfectly well for you. The difference in strength or muscle gains when training at different times of day is small, as long as you consistently train at the same time.

## The exception to the rule

If you have a job that is physically demanding, it may be better to train during lunch than after work. The fatigue from work may then offset the benefits of the optimal physical state later in the day. At least one study shows that in fitness center employees working a morning shift, peak performance occurs before work, followed by lunch, followed by after work. So if your work is particularly fatiguing, it may be best to schedule all your training sessions before work or during lunch. Note that this particularly holds for physical fatigue, not necessarily mental fatigue.

## Take home messages

- Your circadian rhythm is a 24-hour cycle of biological activity set by your internal clock. Your sleep-wake cycle is one of many systems influenced by your circadian rhythm.
- Your hormonal milieu, gene expression and core body temperature have a circadian rhythm. Together, they normally result in peak physical condition to train in the late afternoon to early evening for most individuals.
- The best time to work out for peak performance and possibly greater long-term gains is generally between 14:30 and 20:30 h if you have a regular sleep-wake cycle.
- You can determine the optimal time to train by monitoring your maximum resting heart rate and training performance. Some people do just fine training in the morning, as people can have different chronotypes.
- If you can't train when your body is primed to do so, supplement with caffeine pre-workout and schedule your workouts when you can always train. Your biorhythm can adapt very well to training in the mornings.

- Getting in your workouts in the first place is always much more important than when you do them. Optimizing your biorhythm is fine-tuning. Adherence is crucial.

## Intermittent fasting (IF)

Often, when people say 'intermittent fasting', they really mean 'skipping the first meal of the day'. Intermittent fasting sounds cooler and more scientific, but it's actually a deceptive term here and it's important to realize this.

Say we take a pretty common intermittent fasting set-up where someone eats her last meal close to bedtime at midnight, skips the morning meal and then has her first meal at lunch at work at 12 AM. Compare that to the average person that eats dinner at 6 PM and has her breakfast at 8 AM. The second person actually has a 2 hour longer daily intermittent fast than the first person that is 'doing intermittent fasting'.

So everyone practices intermittent fasting. It is only the duration and timing of the fast. In fact, this is why we call the first meal of the day breakfast: **break**ing the **fast**. So technically the person in the first example above has breakfast at lunchtime AKA brunch.

From an evolutionary perspective, intermittent morning fasting really isn't that special for the body. Many people in the intermittent fasting community obsess over if they should extend the overnight fast to 8 or 9 hours. The physiological response for your body composition between those scenarios is virtually identical. As a frame of reference, the longest successful fast lasted more than a *year*: a Mr. M literally lived on a multivitamin with some yeast for 382 days and went down in bodyweight from 207 kg (456 lb) to 82 kg (180 lb) in the process. This was in a morbidly obese person, but even an 80 kg (176 lb) individual at 10% body fat still has 8 kg (18 lb) of fat mass. Just half of that provides the body with well over 30k kcal of energy, enough to survive a net Caloric deficit of 2000 kcal for 15 days without burning any lean body mass.

Now that we've got our terms straight, we can delve into the research on the effectiveness of postponing breakfast and other intermittent fasting protocols.

## Consistency vs. timing

The first thing opponents of postponing breakfast will point to is that people who postpone breakfast are generally fatter than people who don't. Using this as an argument against postponing breakfast is a classic case of mistaking a correlation for causation. You are comparing 2 groups of people here that vary in several key ways. On the one hand, you have people with a regular breakfast routine. On the other hand, you have people without a plan for breakfast. You're talking about people eating on the run to work that are more likely to snack and consume ready-to-eat convenience foods. In fact, breakfast skipping is *the* meal pattern most strongly related to poor diet quality. It's no surprise that a more irregular lifestyle is more likely to make you fat. "Failing to plan is planning to fail."

When correcting for the regularity of breakfast consumption, consistently skipping breakfast is just as effective to prevent weight gain as consistently eating it, with both being considerably more effective in the general population than an irregular breakfast eating habit.

Moreover, an irregular meal pattern is not just a lifestyle concern. The regularity of your meal pattern has small but considerable physiological effects. By definition, an irregular meal pattern has you eating at times when your circadian rhythm is not adapted to digest nutrients. This causes slight disruption of postprandial metabolism – how your body reacts to food – with the following adverse effects.

- Higher fasting total and LDL ('bad') cholesterol [though not here].
- Decreased postprandial insulin sensitivity [though not here]. When you eat at a time your body is not accustomed to, some people produce more insulin than normally.
- Higher blood glucose levels [2].
- A disruption in the circadian rhythm of your appetite leading to more hunger [2, 3, 4].
- A disruption in the circadian rhythm of cortisol production and an increase in total cortisol production across the day.
- Higher blood pressure.
- A lower thermic effect of food (TEF) [2] as a result of decreased insulin sensitivity. When you eat at irregular times, your metabolism does not increase as much as normal during the digestion of the food. In one study the thermic effect of food decreased almost 50% during the 2-week transition from a regular to an irregular meal pattern. That means if your TEF is normally on the high end of 25%, an irregular meal pattern could drop that close to 12.5% and thereby decrease your total daily energy expenditure by 12.5%. Alhussain et al. (2021) found a 21% lower TEF energy expenditure after eating 3-9 meals a day compared to eating a constant 6 meals a day for 2 weeks. Assuming a 20% total TEF, this would correspond to an approximately 5% lower total daily energy expenditure.

Snacking is also associated with long-term fat gain, even though meal frequency per se is not.

Some researchers even argue that a regular eating pattern is a key habit to live over 100 years.

Women may also experience less satisfaction from eating meals at irregular times.
Men's psychological responses to a meal don't seem to be affected by a meal's timing.

206 Curr Nutr Rep (2014) 3:204–212

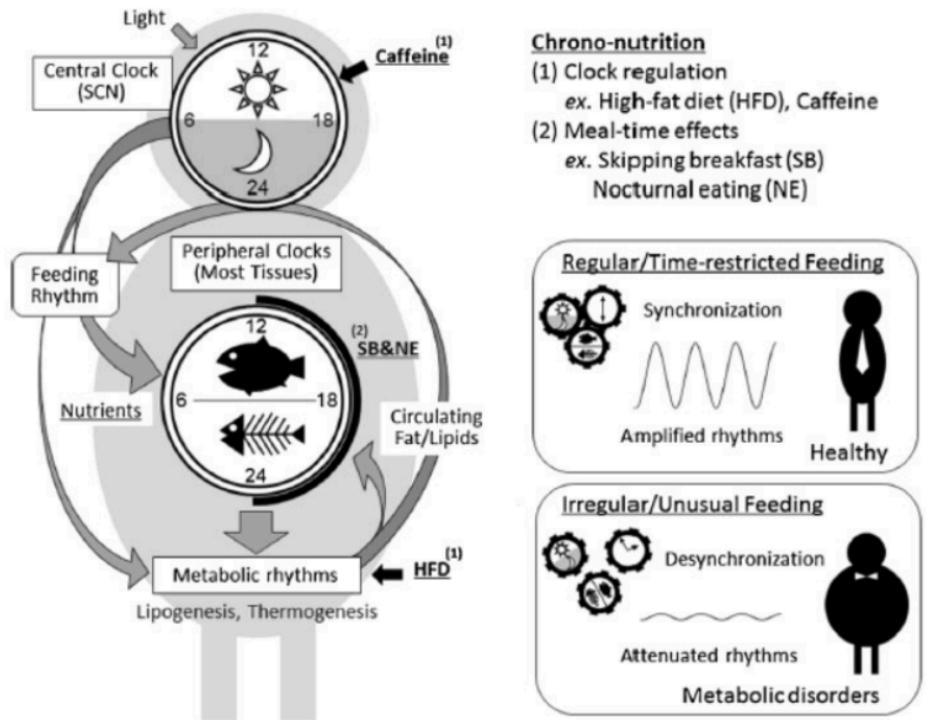



**Fig. 1** Schematic representation of the circadian clock system and chrononutrition. Light/dark cycles entrain the central clock in the suprachiasmatic nucleus (SCN) dominating activity rhythms, whereas feeding cues determine the phase of peripheral clocks that dominate local metabolic rhythms. Both nutrients and meal timing can affect the clock system, thus "chrononutrition" has two aspects: 1) nutrients/food components regulate the clock system, e.g., caffeine prolongs the period of circadian clocks and the locomotor activity rhythm, and high-fat diets alter the rhythms of lipogenesis, circulating lipids, locomotor activity, and feeding behavior; 2) meal-timing affects output of the clock system, e.g., skipping breakfast and nocturnal eating increases risk of obesity, whereas time-restricted feedings prevent metabolic disorders induced by high-fat diets. Regular/time-restricted feedings synchronize and amplify the rhythms of clock system, whereas irregular/unusual feedings cause desynchronization and attenuate the rhythms, probably leading to metabolic disorders

*How an irregular meal frequency can cause metabolic disorders.*

To maintain a regular biorhythm, try to have your meals within 1 hour of their habitual time. For example, if you normally have dinner at 7 PM, try to always have it in between 6-8 PM.

In further support of the regularity of meal times rather than their absolute times, intermittent fasting in the morning and evening do not significantly differ in their metabolic effects [2, 3] in studies resulting in equal body recomposition. Time-restricted daily feeding and alternate day fasting with similar total energy intakes also don't significantly differ in their cardio-metabolic effects. Thus, aside from anabolic window considerations, *when* you fast doesn't seem to matter, as long as you do so consistently.

The adverse effects of skipping meals may have been considered worth it if it allowed you to easily create an energy deficit. A meta-analysis found that on average, people do end up with a lower energy intake when skipping (read: delaying) breakfast, but in several studies skipping meals tends to result in complete energy compensation afterwards [2]. This means that you will be hungry to make up for the decreased energy intake later in the day and often end up consuming the same total amount of energy as if you had eaten the meal anyway (or you go hungry). Energy compensation isn't always complete, but this is mainly found in studies where the early breakfast is low in protein and therefore not very satiating to begin with. We'll later go into who is likely to adhere best to intermittent fasting, as this varies per individual.

An irregular meal frequency is unquestionably suboptimal for your body, but how is this relevant to people practicing intermittent fasting (IF) where macros and the daily fast are meticulously controlled every day? While consistent intermittent fasting is better than irregular breakfast consumption, intermittent fasting does not mean you have regular meal times. Many IF diets have 'eating windows', such as from 16:00-24:00 h. This means a person can sometimes have 1 enormous meal and at other times snack more or less continuously throughout the eating window. This variance can cause the metabolic disruptions mentioned above. Having an eating window in your diet is thus generally suboptimal compared to having set meal times.

Now what about if you control your macros *and* your meal times?

## Fasting for fast fat loss?

A substantial literature has compared groups of participants with and without fasting periods of various lengths with the same total daily average protein and energy intakes. Under these conditions, there is no difference in effectiveness between intermittent or constant energy restriction for fat or weight loss [2, 3, 4, 5, 6]. Whether you eat an early breakfast or not, as long as you do so consistently, does not impact fat loss or overall body recomposition [2, 3, 4]. Alternate day fasting type protocols and other forms of intermittent energy restriction also result in similar fat loss as constant daily energy restriction according to multiple systematic reviews. In conclusion, fasting per se does not affect fat loss, independent of energy intake.

From an evolutionary perspective, most fasting diet protocols are rather trivial. Humans should be able to fully adapt to eating few meals and not eating immediately after waking up. Your body is easily capable of fasting for prolonged periods in a day. In fact, during a complete fast your energy expenditure increases by a few percent during days 3-4, as after about 2 days, the low blood glucose levels trigger the release of catecholamines like noradrenaline, presumably with the evolutionary purpose of stimulating you to find food. Only after several days of fasting does your metabolic rate downregulate.

In conclusion, whether you eat breakfast or implement regular fasting periods in your diet, as long as you do it all consistently, generally does not affect our body composition or metabolism. Ideally, keep your meals within a 2-hour window. For example, if you normally eat a meal at noon, try to always have that meal in between 11:00 h and 13:00 h.

## Fasting and muscle growth

Opponents of intermittent fasting tend to portray intermittent fasting as highly unnatural and extremely bad for your physique. Yet the above studies have already shown us that intermittent fasting often does not negatively affect our body composition compared to regular diets, although most of those data are in sedentary individuals. In strength trainees, multiple studies confirm that time-restricted feeding diets have similar effects on strength development and body recomposition as diets with constant daily energy restriction with the same average energy and protein intakes. [Tinsley et al. (2019)] randomized female strength trainees into 2 groups. Both groups were given the same macros intended to establish a small energy deficit and both groups supplemented whey protein.

1. The IF group consumed all food between 12:00 and 20:00 h and trained sometime in this window (so no fasted training and they had post-workout nutrition).
2. Another IF group with the same protocol consumed HMB. We'll discuss HMB in more detail in the supplements module of the course. It didn't seem to affect the results in this study with regard to IF.
3. The control group consumed an early breakfast and could eat all day, ending up with a ~13 hour eating window instead of the ~8 hour IF eating window.

The IF and control group achieved similar results with no significant differences between groups in muscle growth (increase in fat-free mass and muscle thickness of the elbow flexors and quads), fat loss or strength development (6 measures including 1RM bench press and leg press). One exception: the IF group supplementing HBM achieved less quadriceps growth (significant in PP, strong trend in ITT).

Results were overall the same in the total intention-to-treat analysis (ITT) and the stricter per-protocol (PP) analysis. Resting energy expenditure and standard health biomarkers also didn't differ between groups (except for pulse wave velocity, a measure of arterial stiffness, which was all over the place).

Mood states, sleep quality and eating behaviors also didn't differ significantly between groups.

These findings suggest IF with an 8-hour eating window does not affect our body composition, training progression or basically anything at all.

Similarly, Stratton et al. (2020) compared groups of intermediately trained men with either no eating time restrictions or an 8-hour eating window over a 4-week RCT with equal total daily macronutrient intakes. Both groups were in energy deficit. There were no significant differences in how the diets impacted the men's body composition, strength development or subjective evaluation of the diet, including satiety, perceived recovery, perceived stress and dietary restraint. There were also no differences in how the diets affected the subjects' metabolic rates and overall hormone levels, specifically testosterone, leptin, ghrelin and adiponectin.

A small study on bodybuilders during Ramadan by Trabelsi et al. (2013) found no change in body composition during the month of daytime fasting when macronutrient intake was kept the same. Since there was no non-fasting control group, we can't say whether the fasting impaired muscle growth or strength development, but the study at least shows fasting per se has minimal effects on our body composition. Other research on Ramadan fasting, where people fast as long as the sun is up, generally finds negative effects on athletic performance, though the effects are slight and confounded by poor study designs and fluid restriction.

Several other studies have been published in which total macronutrient intakes were not equated between groups: Tinsley et al. (2016), Moro et al. (2016), Kotarsky et al. (2021) and Moro et al. (2021). In these studies, the IF group generally ended up consuming fewer calories than the group with a larger eating window, and as a result, lost more fat, whereas the control group showed a better trend for lean mass changes. In another randomized cross-over study by Correia et al. (2023), there were no significant between-group differences in fat loss or muscle growth between 16:8 time-restricted eating and the habitual diet of strength trainees. These results are overall consistent with the idea that IF per se has minimal effects on our body composition and total macronutrient intake is far more important, at least when exercise isn't done fasted. From a practical point of view though, these studies indicate intermittent fasting is generally better suited for cutting than for bulking, as it tends to unintentionally reduce energy intake.

We have only one study on alternate day '5:2' fasting compared to constant daily energy restriction in strength training individuals. Keenan et al. (2022) had untrained individuals start an 8-week strength training program with either a constant 20% daily energy deficit or 2 semi-fast days with a very low energy intake, as well as a lower protein intake, ending up with the same total weekly average protein and energy intakes. Both groups achieved similar body recomposition and strength development. In sedentary individuals, the data on alternate day fasting type diets are more conflicting but are overall consistent with null effects. A 2019 meta-analysis by Roman et al. suggests alternate day fasting worsens lean body mass losses in overweight individuals while dieting *if and only if* the diet has days in energy maintenance or surplus, but a 2011 review by Varady and a 2016 meta-analysis by Alhamdan et al. on very-low-calorie diets found the opposite, that alternate day fasting protocols tend to preserve lean body mass better and may result in greater fat loss when the total weekly energy deficit is large. The difference in results is likely due to methodological problems, such as the measurement method and timing of body composition (e.g. BIA is sensitive to hydration status and therefore fasting may bias its results) and macronutrient intakes, especially protein intake on the ad libitum diet days.

Overall, the results in strength training individuals seem to be like those in sedentary individuals: IF per se provides no body recomposition advantage and does not alter energy expenditure.

Proponents of intermittent fasting often cite there is a severalfold increase in growth hormone production during fasting [2, 3] as an argument that IF increases muscle growth. However, this is misguided. The increase in growth hormone is not a net anabolic event but a compensatory anti-starvation response that shifts fuel substrate use from glucose and amino acids towards lipolysis and ketone production. Part of the cause of the growth hormone release is reduced hepatic insulin-like growth factor-1 (IGF-1) production, resulting in less negative feedback to the pituitary to produce growth hormone. So during a fast you end up with more growth hormone but less IGF-1. IGF-1 is more directly active in skeletal muscle to produce growth than growth hormone. The result is that while fasting-induced growth hormone secretion does help counteract muscle protein breakdown, it does little to increase muscle protein synthesis when you're fasted and you remain in negative whole-body protein balance. If you don't consume protein, your body will never be in positive protein balance. You can thus think of the growth hormone as a compensatory anti-starvation response. Put simply, there's nothing anabolic about not eating.

Growth hormone also drives the insulin resistance many people experience during fasting, so more growth hormone isn't always desirable.

In fact, it's only a matter of time before you start losing muscle during a fast. Absolute muscle loss will not typically occur within a day, but protein breakdown rates start to increase in between 15 and 30 hours of fasting. Correspondingly, fasting for 20 hours decreases resting energy expenditure and mTOR signaling, an important component of anabolic gene expression. This would suggest 20+ hour fasts may negatively affect your muscle mass and fat loss. However, weight loss, protein balance, thyroid activity and glucose and insulin metabolism were not yet affected, nor in a study by Cienfuegos et al. (2020) comparing 20-hour and 18-hour fasting, but this was in sedentary, obese individuals. The decrease in energy expenditure was only 59 Calories compared to the regular diet, but the subjects were kept in the lab throughout this entire period for repeated blood testing. It is plausible that fasting for these periods decreases energy expenditure considerably more in free-living conditions. The decrease in mTOR activity may also be more relevant in more advanced, strength-training individuals. On the other hand, a super-compensatory anabolic response after the fasting may make up for the lost anabolic signaling and metabolic activity during the fasting. Still, based on the increased protein breakdown, impaired anabolic signaling and lower energy expenditure during fasts over 20 hours, it's advisable to limit fasting periods to 16 hours. In Menno's experience with clients, shorter fasts are often better tolerated long-term.

There is also a paucity of data on IF in energy surplus, so it's unclear if bulking on an IF diet is equally effective as with a larger eating window.

## The protein sparing modified fast (PSMF)

Knowing that even complete alternate day fasting days are viable for fat loss, as strength trainees we can take advantage of this by programming large energy deficits outside our anabolic windows to free up calories to put into our anabolic windows, where they can possibly help fuel muscle growth. Instead of complete alternate day fasting, we're likely better off with what are called protein sparing modified fasts (PSMFs).

A PSMF is a period where the regular meal frequency is preserved, but the meals are reduced to the optimal protein intake with a minimal intake of the other macros. The PSMF is a highly successful medical practice for obese individuals with few complications [2, 3], in contrast to what you may intuitively expect. However, a PSMF cannot be sustained without excessive muscle loss in leaner individuals, as the cumulative energy deficit becomes too large. By restricting the PSMF periods to outside your anabolic windows, you can achieve very time-efficient fat loss and the potential benefits of alternate day fasting with favorable nutrient partitioning.

Calorie cycling with PSMF phases may be useful to keep your appetite in check as well. While energy compensation is generally high on the same day, sleep tends to reduce this effect considerably and acts somewhat like a reset button of your appetite. The day after a 75% energy deficit 'cut day', ad libitum energy intake only increases 7% without any increase the day thereafter. Subjective appetite increased a bit the morning after the cut day, but appetite regulatory hormones were not affected. Other research finds alternating ad libitum dieting days with 75% energy deficit cut days does not affect subjective appetite levels at all, nor does it affect your activity level. Moreover, your appetite during the cut days themselves even decreases. As such, sleep acts as an almost complete reset of hunger levels after the cut day and there is minimal compensation on the days after the cut day.

A PSMF also seems to have inherent appetite suppressing effects compared to going low but not super low in calories. Several studies have found that people are less hungry on very low energy intakes than not-as-low ones. In a study by Davies et al. (1989), the participants reported less hunger on a diet of 330 kcal compared to a group consuming 780 kcal of the exact same meal replacement product. In a study by Wadden et al. (1987), the participants were less hungry on 500 kcal than 1200 kcal in spite of losing significantly more weight. A plausible explanation for the appetite suppressing effect of PSMFs is increased ketone body production. (Remember: ketosis happens on a continuum.)

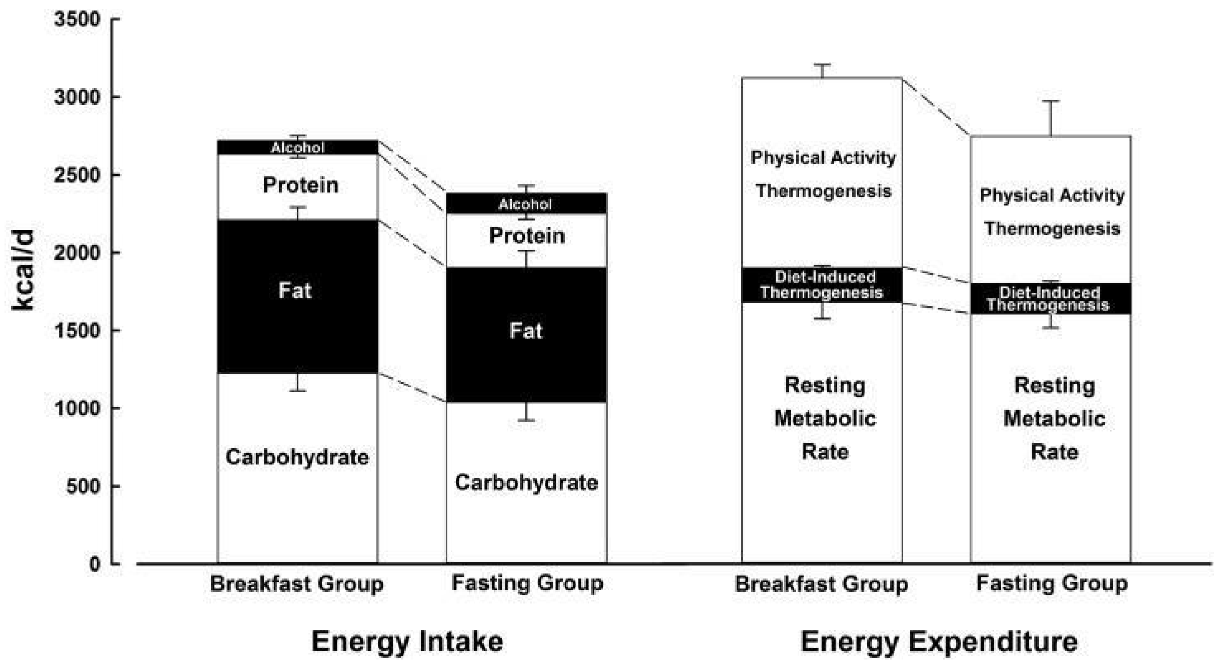
A good PSMF does not mean you live on protein shakes. Micronutrition, dietary fiber, not to mention adherence, are all still important. A good PSMF generally has meals that consist of vegetables or fibrous fruits combined with lean protein sources. Think quark with strawberries, zucchini soup with 1% beef meatballs or white fish and pak choi in soy sauce. A proper PSMF should not feel like torture and is more like an über healthy diet than a fast. Concretely, a PSMF period should look like this:

- Protein is consumed at the optimal level as normal, as per the topic on protein.
- Total energy intake is minimized. Few people can sustain an energy intake below 8.3 times their protein intake. 9.7 times protein intake is a good rule of thumb for a sustainable PSMF in Menno's experience. This means a PSMF day with a protein intake of 150 g has a Calorie budget of 150 g x 9.7 kcal/g = 1455 kcal.
- Dietary fiber intake should still be at or at least near the targets from the course module on carbohydrates.
- All essential micronutrient intakes should still be met.

## Activity level

Before you conclude that intermittent morning fasting doesn't ever change anything and it's purely a psychological question of whether to implement it or not, there's a caveat. Most of the aforementioned research looking at the effect of postponing breakfast measured energy expenditure in metabolic chambers or wards. But in the Bath Breakfast Project, energy expenditure was measured in free-living conditions by linking the data from the lab to combined heart rate/accelerometry, which can be worn across the chest so that subjects can go about their daily lives during the study.

Allowing the subjects to be active was a game-changer. Now the early breakfast eating group had a significantly higher energy expenditure. This was almost entirely due to a higher spontaneous physical activity level. They also naturally increased their energy intake, but they burned all of this energy off: see the data below.




Betts et al. add, “cross-sectional studies have detected slightly higher self-reported overall physical activity levels among breakfast eaters (39), and several recent cross-sectional studies using accelerometry reported correlations between habitual breakfast consumption and physical activity levels, particularly during the morning (40, 41).”

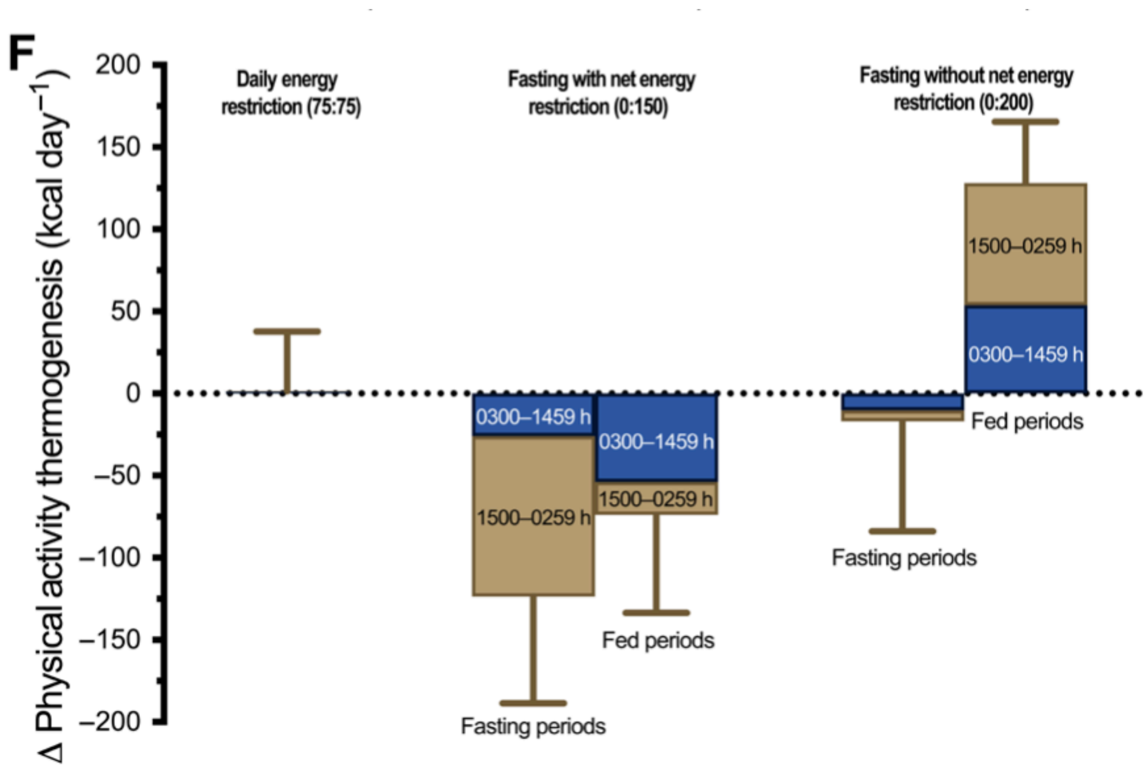
These results are in line with a randomized controlled trial from Tinsley et al. (2016). In this study, the intermittent fasting group restricted their food intake to a 4-hour window on their 4 weekly rest days. This resulted in significantly lower caloric intake than the non-fasting group. Despite consuming the same amount of protein and fewer calories, there was no significant difference in fat loss, muscle growth or strength development between the groups. The similar fat loss with a lower energy intake suggests that the fasting decreased energy expenditure.

However, while total protein intake was not statistically significantly different between groups, relative to bodyweight, the fasting group only consumed 1 g/kg (0.5 g/lb) per day compared to 1.4 g/kg (0.6 g/lb) per day in the non-fasting group. As such, this may have been the cause of the lower energy expenditure, not (just) the fasting. (Remember why protein intake can increase energy expenditure? If not, revisit the protein module.)

Ramadan fasting, which means fasting while the sun is up, has also been found to decrease physical activity levels. Interestingly, total energy expenditure is not affected. This seems to be caused by a shift in activity level from daytime to nighttime and an increase in total waking hours. As such, without the reduced sleep duration and increased nighttime activity, it's likely that total energy expenditure would have been lower. In absolute terms, there was also a ~100 kcal decrease in EE, but it wasn't statistically significant.

In contrast, Halsey et al. (2012) did not find any effect on spontaneous physical activity level as a result of fasting until noon compared to having an early breakfast. However, most of the participants were on-campus students, so their activity level probably wasn't high to begin with. Plus, they found that 'morning persons' who are active in the morning are also more likely to habitually eat an early morning breakfast, supporting an ecological correlation between breakfast consumption and morning activity level.

In 2021, a RCT by Templeman et al. provided more direct evidence that fasting can reduce our physical activity level. Complete alternate day fasting (0% energy intake during 24-hour fasts; 150% during eating windows) led to a significant reduction in energy expenditure from low- and moderate-intensity spontaneous physical activity, especially later into the fasting periods: see the figure below. This reduction in energy expenditure was accompanied with significantly reduced fat loss during the 3-week diet periods.




In conclusion, if you're highly physically active in the morning, you may be able to increase your energy expenditure by having an early breakfast. Intermittent morning fasting may needlessly impair energy expenditure in active individuals. Even if the increased energy expenditure is accompanied with more appetite, being able to consume more food and nutrients is generally favorable when cutting, because a higher energy turnover makes it easier to create an energy deficit and you get to eat more.

## Adherence: who does well on an IF diet?

Since IF diets generally don't have any inherent effects on fat loss or body recomposition, the decision whether or not to practice IF is largely a matter of personal preference. Ease of diet adherence is thus a key consideration. If fasting helps you control your appetite without any downsides, it's probably beneficial to implement it. A 2023 meta-analysis of 17 RCTs found no effect of IF vs. non-IF diets on participants' appetite or diet adherence. There were no significant differences for hunger, fullness, desire to eat, prospective food consumption, bodyweight loss, energy intake, eating behaviors or diet adherence. However, most effect sizes leaned in favor of IF. The IF diets included both alternate day fasting (ADF) type diets and time-restricted eating (TRF) window type diets. Another 2023 systematic review of 16 studies found "time-restricted eating does not result in substantial increases in hunger or other appetite-related measures". A 2019 review also found dietary adherence is similar on average between IF and non-IF diets in the total literature. The equal fat loss in both groups in most studies also inherently indicates dietary adherence was similar. A 2023 RCT further found that time-restricted eating also did not significantly affect quality of life or mood states compared to regular caloric restriction.

While on average fasting and non-fasting type diets have similar outcomes, the results vary substantially across studies. In some research, IF diets have worse long-term adherence, whereas in other research the participants unintentionally ended up with a lower energy intake, indicating the diet was easier. One factor influencing the ease of diet adherence is obviously how well the diet is set up. For example, fasting (almost) completely for full days, as in ADF diets, tends to result in relatively poor long-term adherence.

In addition, there seems to be a relationship between someone's personality traits and their tolerance of fasting. Schlundt et al. (1992) studied the psychological response to dieting with an early vs. delayed breakfast (IF). Overall compliance and psychological response was similar between the diets. These were the most notable findings.

- The fasting group scored higher on negative emotional eating at the start of the study, but this difference disappeared over time. This indicates initial difficulty adjusting to the fasting diet compared to having breakfast early.
- Overall compliance on various measures (diary keeping, analysis of eating behavior and drop-out rate) did not vary between groups. Once the subjects were used to the fasting, they had no more difficulty with the diet than the group having an early breakfast.

These findings are in line with most of the other studies, finding that compliance was similar between groups. However, when looking at specific types of non-compliance, there were interesting differences between the groups.

- The fasting group suffered more from impulsive eating.
- The early breakfast group suffered more from depressive eating (effectively self-medicating), but the difference was very small.
- The fasting group had an easier time incorporating social meals into their diet, because their meals were larger.

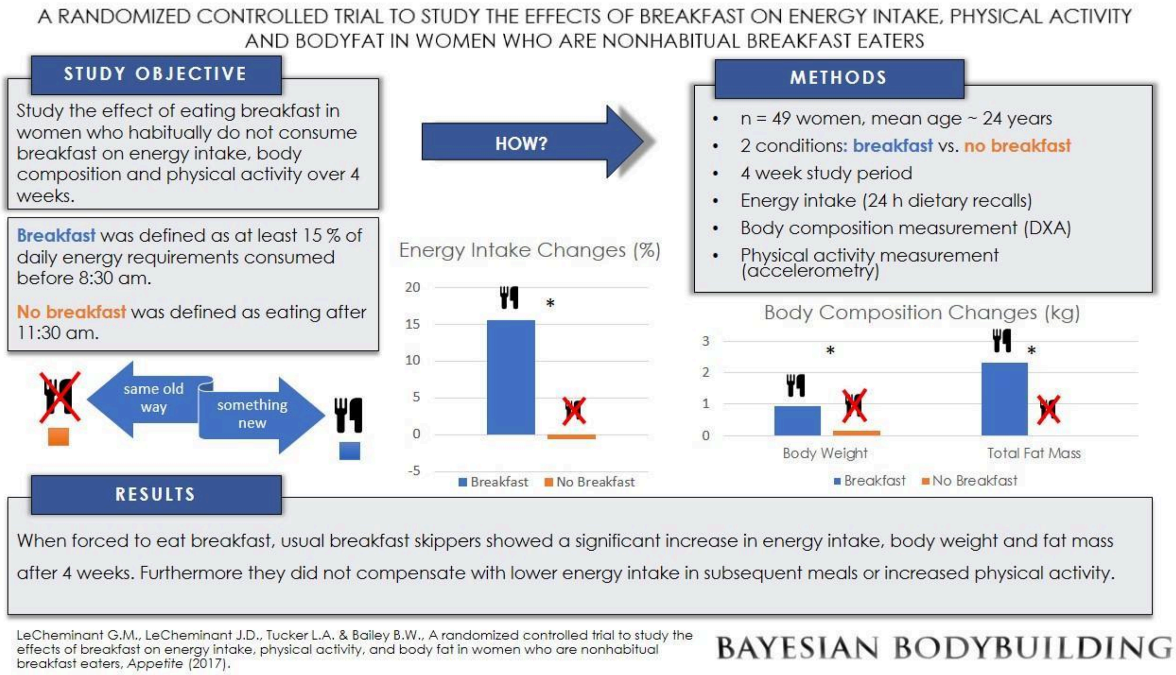
These seemingly subtle differences are supported by Menno's client experiences. People prone to impulsive eating, which is probably most of the general population, have difficulty with extended fasting. The people that thrive on IF are generally calm, introverted, cognitive types. IT workers typically do well on IF diets, for example.

## IF for women

Anecdotally, IF diets are more popular among men than women, but most studies find that women have similar adherence rates on IF and non-IF diets [2, 3, 4]. The only study to actively investigate a sex difference in diet compliance is Halsey et al. (2012). The IF diet consisted of a fast up until noon (IF) compared to having an early breakfast. They found no sex difference for ad libitum energy intake. The researchers also looked at the difference in adherence to the IF diet as a function of whether the participants habitually consumed breakfast or not before the study. Male non-habitual breakfast eaters consumed significantly more energy during the breakfast condition. Furthermore, female habitual breakfast eaters ate significantly more and later in the day under the no-breakfast condition. This suggests that people who habitually eat breakfast have more trouble with intermittent fasting and this effect seems to be stronger in women.

## Natural hunger biorhythm

People that don't naturally like eating breakfast often do well on IF diets. LeChimant et al. (2017) found that women who were natural breakfast skippers did not react well to having to eat breakfast. Consuming breakfast in this population did not result in the normal appetite suppression throughout the rest of the day, resulting in increased energy intake and consequent fat gain. In other words, force-feeding breakfast because it's supposedly 'the most important meal of the day' can sabotage your diet. See the infographic below for further study details.




Halsey et al. (2012) found that habitual breakfast eaters were more likely to be active in the morning, suggesting a link between the 2 predictors of how well someone adheres to IF diets. People that are naturally active and hungry in the mornings probably shouldn't try to fast through the mornings, whereas people that are naturally sedentary and not hungry in the mornings should probably not force themselves to have an early breakfast.

Most people have a natural peak in hunger around 20:00 h, so if someone isn't hungry in the evenings, that's a good indication they're different from the general population in their response to IF. You may argue you could get used to any meal pattern, but research finds the adaptation in metabolism and appetite to fasting is not always complete. Chowdhury et al. (2018) found that 6 weeks of morning fasting did not affect appetite at breakfast or lunch compared to regular breakfast eating. Anecdotally, however, there does seem to be major adaptation: many people can get used to both intermittent fasting and regular breakfast eating if they do so consistently.

If you're the type with naturally little hunger in the mornings, you'll probably have an easier time restricting your energy intake with morning IF. However, longer fasts are not always better. Cienfuegos et al. (2020) found no difference in ad libitum energy intake reduction (not counting calories: just eating to satiety) between fasting protocols with 4 and 6-hour eating windows. Anecdotally, few people prefer eating windows shorter than 8 hours.

## Fasting and health

Our gains are one thing, but how about our health? An abundance of research shows that intermittent fasting benefits your health. However, fat loss diets almost always result in health benefits, as fat loss is generally healthy (discussed in more detail in the health science module). Fat loss very consistently improves insulin sensitivity in particular, as it reduces fatty acid release from fat stores, which in excess inhibits insulin signaling [2]. So the real question is not whether IF is healthy but whether IF diets are health**ier** than calorie-matched diets without IF. And the answer seems to be no. Multiple recent systematic reviews and meta-analyses have found that IF per se does not offer clinically significant health benefits independent of calorie restriction [1, 2, 3, 4, 5]. Some reviews have found slightly variable results, so we'll discuss these in a bit more detail for those interested.

- A meta-analysis by Kim et al. (2022) found that constant energy restriction diets resulted in greater improvements in blood sugar and systolic blood pressure than intermittent energy restriction diets, but no other health or body composition outcomes differed significantly between groups, including A1C.
- A 2021 systematic review and meta-analysis of RCTs by Chen et al. found no clinically relevant health effects of time-restricted feeding in overweight individuals compared to other diets. There were a few health biomarkers with variable results, but those were likely caused by the variable results in body composition outcomes, as energy intake was not controlled for in most studies.
- A meta-analysis by Pellegrini et al. (2019), mostly on Ramadan studies, found equal losses in FFM and fat mass between IF and non-IF groups, which allows us to determine which effects occur independent of body recomposition. There were again no significant differences between IF and non-IF groups for most health biomarkers, including fasting insulin levels, insulin sensitivity and blood lipids. IF diets resulted in statistically significantly but clinically insignificantly

lower blood glucose levels (~2 mg/dL less). Systolic blood pressure decreased more on IF diets in observational research but not in randomized, controlled trials.

- A meta-analysis by Pureza et al. (2020) no significant health effects of IF vs. non-IF diets in the majority of health biomarkers in overweight individuals practicing early time-restricted feeding (morning IF) or not, including metabolic speed (resting metabolic rate), blood lipids (triacylglycerol, total cholesterol, HDL-cholesterol, LDL-cholesterol), insulin, inflammation markers (C-reactive protein and interleukin-6), cortisol, appetite markers (leptin, ghrelin, peptide YY, glucagon-like peptide and appetite) and hemodynamic parameters. The IF groups did experience significantly greater reductions in insulin resistance and fasting blood sugar levels, but energy intake was not controlled, so were these benefits the result of the fasting or the presumably greater fat loss in these studies?
- Probably the fat loss, because a meta-analysis by Borgundvaag et al. (2021) found intermittent fasting offers no benefits for glycemic control ($HbA_{1c}$) in type II diabetics beyond that of calorie restriction.
- A 2020 systematic review on the health benefits of IF in type II diabetics similarly concluded: “The majority of the studies demonstrated insignificant differences between intermittent fasting and continuous energy restriction for measures of glycated hemoglobin A1c and body composition.” While IF proponents often cite positive findings on fasting for insulin and blood sugar control, there are also some studies finding negative effects. Fasting more than 14 hours can acutely impair insulin sensitivity [2] In Kobayashi’s aforementioned metabolic ward study, blood glucose was recorded with a continuous glucose monitoring system and fasting led to an increase in daily average blood glucose levels. In the Bath Breakfast Project, more variable blood sugar levels were found in the afternoons and evenings in the IF group compared to the early breakfast group.

Heilbronn et al. (2012) found that alternate day fasting differently affected men and women. For women, fasting impaired glucose tolerance without affecting insulin response, whereas for men there was no detrimental effect on glucose tolerance and even a decrease in insulin response.

- A 2024 meta-analysis of 10 RCTs in obese individuals concluded that "fasting strategies did not demonstrate superior long-term outcomes compared to continuous calorie restriction". Concretely, there were no significant differences between the 2 diet types for most cardiometabolic health markers, including blood lipids and blood pressure. The fasting diets did lead to a small reduction in insulin sensitivity, but this was not accompanied with an effect on total blood sugar exposure (HbA1C%). The insulin sensitivity was likely related to fat loss, not the fasting. The authors did not require the included studies to have calorie-matched comparisons. This led to the fasting group to lose more fat mass up to the 6-month time point.

Other reviews on IF's health effects had major limitations, such as not having a systematic literature search (incl. Lote-oke et al. (2019)), which creates a high potential for biased study inclusion, or including low-quality studies without control groups or randomization (incl. Moon et al. (2020)), so we won't go into those in detail.

Another often-touted health benefit of IF is autophagy. Autophagy is a cellular protective housekeeping mechanism to eliminate damaged organelles, misfolded proteins and pathogens. Fasting promotes autophagy, but so does energy restriction without complete fasting and via the exact same mechanisms. Autophagy occurs somewhere in the body at any time and increases during any type of catabolic state that stimulates the removal of excess substances from the body. There is no evidence that fasting promotes autophagy more than you'd expect from its degree of energy restriction. A RCT by Templeman et al. (2021) found no significant health benefits, including gene expression of autophagy and inflammation, of complete alternate day fasting compared to similar energy restriction without fasting during a 3-week weight loss diet in healthy adults. Measurements also included insulin sensitivity, postprandial glucose levels and a cholesterol panel.

Intermittent fasting also does not seem to benefit our gut microbiota, independent of body recomposition.

In conclusion, the majority of controlled research indicates intermittent fasting has no significant health effects independent of calorie restriction.

It's worth noting that animal research, particularly in mice, finds far larger health effects of IF than human research. IF research in mice is generally not relevant to humans, because a single day in a rat or mouse is biologically equivalent to about a month in a human.

Interestingly, some of the health benefits of fasting seem to be mediated by ketone production, suggesting ketogenic and IF diets offer similar health benefits and there may be relatively little to gain from combining them.

## Biorhythm disruption

It has been hypothesized that intermittent morning fasting will delay your biorhythm and thereby interfere with your sleep quality. Food is a zeitgeber (literally: time giver) that your body uses to determine when it's time to go to sleep. However, food is a weak zeitgeber compared to light exposure and physical activity level. The biorhythm of melatonin, a key hormonal regulator of sleep, is unaffected by intermittent fasting when you take diet composition, light exposure and physical activity level into account. Correspondingly, sleep quality is unaffected by intermittent evening fasting with an 8-hour eating window. In another study, sleep quality **improved** when switching to an 11-hour self-selected eating window where over 75% of calories were consumed after noon. This may have been due to a more regular lifestyle during the intervention period or the weight loss though, as there was no control group without intermittent fasting. Nevertheless, these data do not support any concerns about IF impairing sleep quality.

More generally, the timing of when you fast doesn't appear to matter inherently for your bodily functions. Intermittent fasting in the morning and evening have the same metabolic effects.

A RCT by Templeman et al. (2021) also found complete alternate day fasting and matched daily energy restriction did not result in significantly different circadian gene expression, suggesting regular fasting per se does not disrupt our biorhythm.

Your body can adapt to almost any eating pattern very effectively. As such, nutrient timing probably won't interfere with sleep quality when practiced consistently. Consistency is the key term for most matters biorhythm related, not the absolute timing itself.

## Conclusion

If intermittent fasting got you out of the bro-age of eating 6 meals a day, carrying around protein powder and Tupperware containers wherever you went, intermittent fasting will feel like the holy grail of easy dieting. However, for people used to a regular 3-meals-a-day diet, intermittent fasting can be difficult to adjust to. Objectively, the physiological responses to intermittent morning fasting and having an early breakfast are not large. There are no intrinsic metabolic differences up to fasting periods of at least 20 hours, though at that point muscle growth may be adversely affected. Since fasting periods longer than 16 hours may increase the risk of muscle loss and don't seem to offer any further benefits in terms of hunger reduction or health outcomes, it's generally advisable for strength trainees to fast for no more than 16 hours.

Intermittent fasting can be slightly detrimental to someone's insulin sensitivity and it has the potential to seriously limit spontaneous physical activity and mental energy levels. Hunger levels are generally not affected, except in individuals with very little natural hunger in the morning (or around the fasting time). Diet adherence is worse in some people, especially women and individuals with poor carb tolerance, yet better in others, namely controlled, sedentary men and individuals with low natural appetite during the fasting hours.

The table below summarizes when intermittent morning fasting is suitable for a person. These criteria generally make intermittent fasting particularly suitable for male office workers and particularly unsuitable for in-gym personal trainers and overweight women.

| Indications | Contraindications |
|---|---|
| Susceptibility to depressive eating | Being active in the morning |
| Having social meals in the evenings | Susceptibility to impulsive eating |
| No natural hunger in the mornings; natural inclination to skip breakfast, especially if male | (Pre-)metabolic syndrome and indications of poor carb tolerance |
| | Natural hunger in the morning; natural inclination to eat breakfast, especially if female |

Alternate day fasting has a surprisingly good track record in research, but it is not recommended for lean or strength training individuals. Instead, when alternate day fasting is desired, PSMF periods are advisable to create a large but short-term energy deficit without impairing muscle growth.

## Circadian rhythm calorie timing

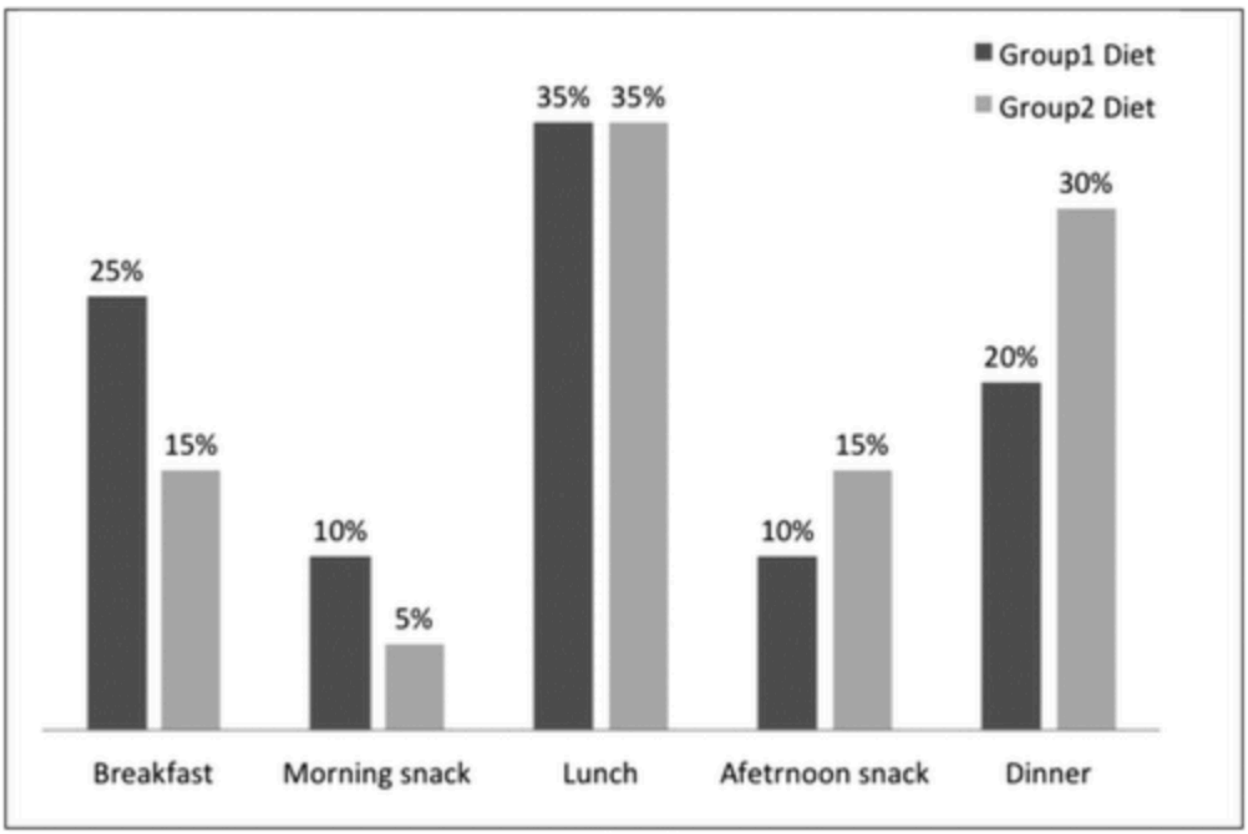
Since IF is just as effective for most people as having an early morning breakfast, the saying ‘breakfast is the most important meal of the day’ seems to have no merit. However, multiple studies have in fact found greater fat loss with larger breakfasts and smaller dinners vs. smaller breakfasts and larger dinners. A 2022 meta-analysis of the total literature concluded: “distributing energy intake with a focus on earlier intake resulted in significantly greater weight loss (–1.23 kg).” The meta-analysis included studies with very different designs, including studies with different macronutrient intakes in both groups and some studies with exercise, so let’s look at the most relevant studies for our purposes in more detail to see if you should indeed consume most of your calories in the early part of the day (on rest days).

1. In Jakubowicz et al. (2013), overweight women with metabolic syndrome were randomized into two isocaloric (~1400 kcal) weight loss groups, a big breakfast (700 kcal breakfast, 500 kcal lunch, 200 kcal dinner) or a big dinner group (200 kcal breakfast, 500 kcal lunch, 700 kcal dinner) for 12 weeks. The breakfast group had better improvements in weight, waist circumference and all measures of carbohydrate intolerance (fasting glucose, fasting insulin, insulin resistance and an oral glucose challenge). The breakfast group also achieved better appetite suppression.

2. In Kahleova et al. (2014), type II diabetics were randomized to either a 2-meal group with a big breakfast and lunch or a 6-meals-across-the-day group. Despite the groups consuming the same macros, the big breakfast group lost more weight and achieved better insulin sensitivity, lower blood glucose levels and lower insulin production (measured by C-peptide). There was also a trend for less of a decrease

in basal metabolic rate. Since meal frequency does not have these effects and neither does intermittent fasting, it is likely that the beneficial effects of the 2-meal group were caused by having a big breakfast.

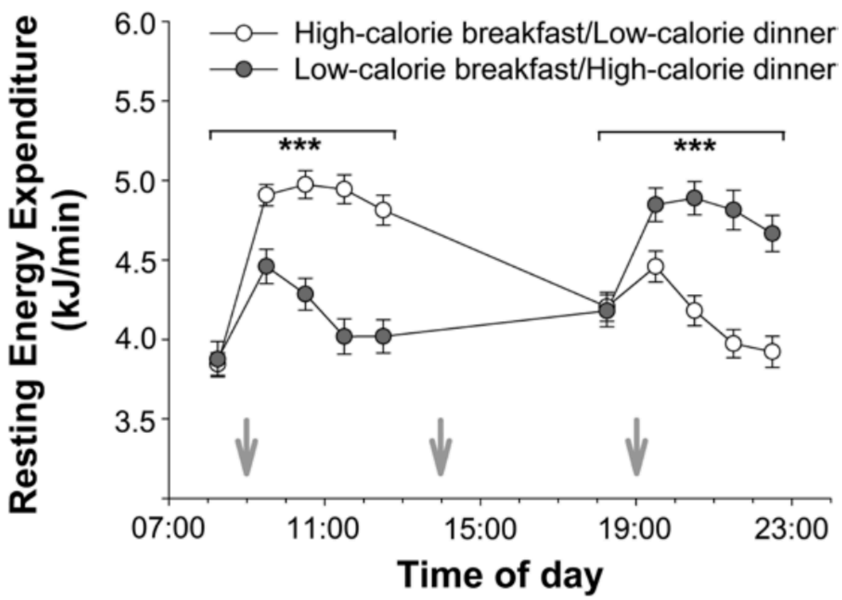
3. A study by Lombardo et al. (2014) in overweight female homemakers found that having most of the day's calories in the AM led to greater fat loss than having most of the day's calories in the PM. The image below shows the diet calorie and macro distributions (spelling error courtesy of the authors).




4. A study by Madjd et al. (2016) found that overweight women lost more weight and achieved a greater improvement in carb tolerance when consuming 50% of their energy intake at lunch compared to at dinner with the same daily total

> macronutrient intake. In this study, both groups consumed an early morning breakfast, indicating that it's not an early breakfast that has the beneficial effect but a general trend for calories to be frontloaded in the day. This interpretation also aligns with the general finding of the IF literature that whether you have an early breakfast or not does not impact fat loss, given the same energy intake.

Why would frontloading energy intake in the day improve fat loss? One line of research has focused on insulin sensitivity. Glucose tolerance and muscle insulin sensitivity are higher in the morning than later in the day. Corresponding with the circadian rhythm of glucose tolerance, in type 2 diabetics, not having breakfast impairs insulin production throughout the rest of the day, causing greater increases in blood sugar after lunch and dinner (postprandial hyperglycemia) than when breakfast was consumed [2]. In other words, a big breakfast improves glycemic control in type II diabetics. Women with polycystic ovary syndrome, which is associated with insulin resistance, also experience an improvement in insulin sensitivity and ovulation rate when they consume most of their calories at breakfast instead of at dinner. None of this should directly influence fat loss for healthy individuals, but in carb intolerant individuals, it could have indirect effects on fat loss similar to those discussed in the carbohydrates module on carb intolerance, including increased appetite and a decreased activity energy expenditure. Insulin sensitivity also correlates with the thermic effect of food (TEF). Some research has indeed found greater thermogenesis. Richter et al. (2020) found that a high-calorie breakfast and low-calorie dinner increased the thermic effect of food by factor 2.5 (!) compared to an isocaloric diet with a high-calorie dinner and a low-calorie breakfast in non-overweight men. Vujovic et al. (2022) also found reduced daily energy expenditure when all meals were delayed by 2.5 hours. However, both were only 3-day studies, so the effects may have been caused by biorhythm disruptions. The TEF is also substantially lower during night shifts, but that is likely due to circadian misalignment, not necessarily due to an inherent lower TEF at night. Circadian misalignment effects should dissipate over time as the body habituates to the new eating pattern. Another major limitation of both studies is that they only measured wake-time energy expenditure. Since dietary thermogenesis can last over 6 hours after a meal, it occurs partly at night when you have a late or large dinner. As you can see in the image below from the Richter et al. study, the researchers likely did not measure all the TEF from the big-dinner group. Thus, the 24-hour total energy expenditure may well have been the same in both groups.




*Frontloading energy intake increases the thermic effect of food in the morning and during the daytime, but the TEF seems to be lower at nighttime, plausibly resulting in the same 24-hour total. Source*

To conclude, one potential reason for the greater weight loss success of bigger breakfasts in the literature is that it may offset the negative effects of carb intolerance due to the inherently higher insulin sensitivity in the mornings. Since virtually all the subjects in the 2022 meta-analysis and aforementioned studies were overweight, carb intolerance is plausible and could explain their impaired weight loss even under isocaloric conditions.

However, it's very likely that most studies did not result in isocaloric conditions and any weight loss differences were in fact the result of lower daily energy intakes in the bigger-breakfast groups. Most of the differences in fat loss were probably caused by better dietary adherence, not a physiological mechanism, because multiple other controlled interventions found no effect of daily calorie timing in sedentary populations.

1. A well-controlled study by Versteeg et al. (2018) found that obese men consuming 50% of their calories either at breakfast or dinner but with the same total macronutrient composition lost the same amount of weight and energy expenditure and achieved the same improvement in glucose control and insulin sensitivity. Energy intakes were 50/25/15% at breakfast/lunch/dinner in the breakfast group and 15/35/50% in the dinner group with the same total macro composition. This study's strength was that all meals were provided for at home, so compliance was less likely to be a confounder than in most of the other studies on this topic.

2. Jakubowicz et al. (2012) also found no direct positive effects of a big breakfast in obese individuals. Both groups consumed a 1400 kcal diet with enough protein: the difference was that they consumed either 600 or 300 kcal at breakfast or dinner. After 16 weeks, weight loss and waist circumference were similar in both groups. However, the bigger breakfast group did have fewer cravings, less hunger and better carb tolerance at breakfast. After the experiment, the smaller breakfast group also regained more fat, indicating a big breakfast is probably easier to stick to for obese individuals.

3. Ruddick-Collins et al. (2022) found no difference between overweight individuals on isocaloric and isonitrogenous diets that either morning-loaded or evening-loaded their calories (45% at breakfast, 35% at lunch and 20% at dinner vs. 20% / 35% / 45%, respectively). This study was well-controlled and all meals were provided to the participants. Both diets produced similar weight loss and health outcomes, with no differences in energy intake or expenditure over the 4-week diets. However, consuming most calories early in the day resulted in lower daily subjective appetite and hunger.

Other research shows type 2 diabetics tend to automatically eat less after a large compared to a small breakfast and a high protein intake at breakfast is more satiating than that same protein consumed at other times of the day, at least in overweight individuals [2]. Overweight individuals thus tend to experience less hunger when they have satiating meals early in the day. Given that overweight individuals often have notoriously poor diet adherence in scientific experiments and self-reported energy intakes are notoriously unreliable, it's likely that the smaller breakfast groups in the above studies suffered more from impulsive snacking and didn't log these unplanned snacks.

Some non-overweight individuals also benefit from big breakfasts for appetite control. In Richter et al. (2022)'s aforementioned study, the bigger-breakfast group also experienced lower excursions in blood sugar and insulin after their meals and less hunger throughout the day than the bigger-dinner group. These subjects were not overweight. This finding may seem to conflict with the IF literature, which shows that most people end up eating roughly the same number of calories, or even fewer calories, when they postpone their breakfast. One reconciling interpretation of these 2 bodies of literature is that a small breakfast is bad for appetite management but no breakfast at all can be fine. In other words, if you're going to have breakfast, it should probably be a substantial, high-protein breakfast, not just some cereal or bread. Low-protein snacks can anecdotally increase your appetite, so you're sometimes better off fasting to prevent hunger pangs.

Regardless of mechanism, the evidence favors big breakfasts for individuals with poor carb tolerance and overweight individuals in general. A big breakfast tends to make diet adherence easier for individuals prone to impulsive snacking. Since intermittent morning fasting inherently backloads calories and has been found to reduce insulin sensitivity, it is probably not ideal for most overweight individuals. For overweight individuals, the conventional wisdom to eat a large breakfast seems to be sound advice. Given that most of the research is in women, this particularly goes for women. The evidence in men is less convincing so far.

For serious strength trainees, the relevance of circadian rhythm calorie timing is questionable. Intense exercise is so good at improving insulin sensitivity that in exercising individuals the relevance of the greater insulin sensitivity in the morning is very slight. As such, a high training frequency can make intermittent morning fasting more tolerable. In general, lean, strength trained individuals with normal carb tolerance don't need to have an early breakfast for normal glucose control and should have no problems with intermittent morning fasting.

## Late night eating

Conventional wisdom says eating late at night makes you fat. Epidemiologically, this is true. People that eat late at night tend to gain more weight than people that don't and the reason for this is that they consume more calories. Late-night snackers tend to consume higher-calorie foods and have a larger daily eating window than earlier eaters.

This is very similar to how breakfast skippers tend to have worse diets than regular breakfast eaters in epidemiological research, but when we look at randomized, controlled experiments, we see that whether someone eats an early breakfast or not does not affect their body composition, given the same total macronutrient intakes.

You may remember from the protein module that Keim et al. (1997) found consuming more of the day's calories in the later part of the day led to a *greater* decrease in body fat percentage. The researchers compared two nutrient timing patterns in women on a 12-week weight loss diet. The women did 6 weeks of the diet with their calories and protein frontloaded (35% at breakfast, 35% at lunch, 15% in the afternoon and 15% in the evening) and 6 weeks with their calories backloaded (15% at breakfast, 15% at lunch, 35% in the afternoon and 35% in the evening), in a randomized order. They trained after breakfast with full-body strength training 3x per week (not near failure though) and cardio 5x per week. In addition to all women being their own control, another big strength of the study was that the women lived in a metabolic ward where all food intake was controlled, so program adherence was forced to be 100%. Eat, train, sleep, repeat. The backloading diet resulted in significantly better nutrient partitioning with better fat-free mass retention (no significant loss) and a greater reduction in body fat percentage. Two limitations of the study were that 1) the sample size was only 10, although this is not too bad for a cross-over study in a metabolic ward, and 2) they used bioelectrical impedance analysis (BIA) to measure body composition, although this limitation was offset by doing measurements 2x each week.

In 2024, Vlahoyiannis et al. compared 3 diets in trained individuals doing strength and endurance training. The diets had the same total macronutrient intakes but differed in how late they consumed many of their carbs and thereby calories.

1) No carbs anymore after their evening workout.

2) 40% carbs after their evening workout with a low glycemic index (GI).

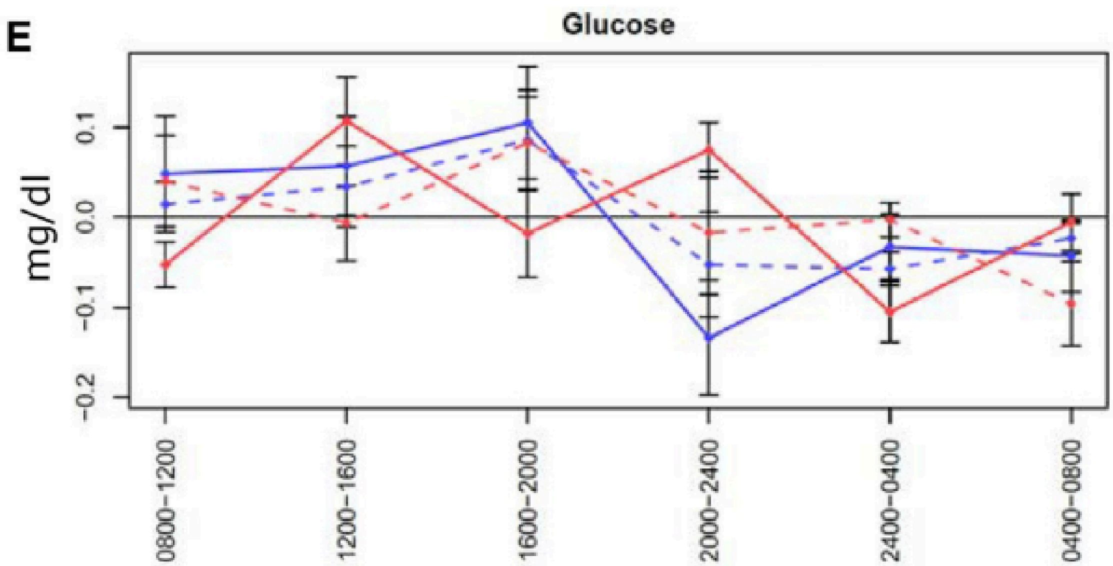
3) 40% post-workout carbs with a high GI.
After 4 weeks, there were no significant differences between the groups in fat loss, fat-free mass gains or any physical performance indicator, including 1RMs. Notable study limitations include its short duration and body composition assessment by bioelectrical impedance (BIA) and skinfold calipers.

Other studies that directly investigated the timing of food intake in otherwise identical diets were a bit less clear in their results. In a study by Madjid et al. (2020), overweight women were randomized to a weight loss diet with the last meal consumed either at 19:00 h or 22:30 h. The late-night eating group didn't achieve the same improvements in health biomarkers and lost less fat, despite self-reporting the same total macronutrient intakes. This finding would suggest eating late at night does indeed cause metabolic disruptions, but that would be at odds with prior research finding intermittent fasting in the morning and evening have the same metabolic effects. The researchers also note that there is no established mechanism why late night eating would reduce fat loss, other than via increasing energy intake. Given the limitation of self-reported energy intake, in particular social desirability bias, it's plausible that the late-night eating group ended up with a higher actual energy intake than the group that consumed dinner at conventional hours. They had to increase the length of their daily eating window and it's very likely that they still consumed a meal of some kind around dinnertime, as their families and friends presumably ate around this time.

Allison et al. (2020) performed a much more tightly-controlled randomized cross-over trial in reasonably healthy adults. Three meals and two snacks with comparable energy and macronutrient contents were provided during two 8-week, counterbalanced conditions separated by a 2-week washout period: daytime with intake limited to 0800 h-1900 h and delayed with intake limited to 1200 h-2300 h. Since the researchers

provided the study participants with meals, compliance was likely better than in most studies and provided and reported energy intakes were indeed almost identical.
The researchers interpreted the results as a big win for the daytime group, but a closer look at the results portrays a different picture. There was a trend for weight loss in the daytime compared to the delayed eating group, but this was not fat. In fact, DXA total body fat levels decreased in the delayed group but increased in the daytime group ($p$ = 0.13 between groups). Lean body mass changes were similar between groups. Resting energy expenditure and self-reported physical activity level trended to be *higher* in the delayed eating group. So what was the extra weight in the delayed eating group? Presumably digestive mass or water. Testing was performed in the morning, so they didn't fast as long before the tests.

The biorhythm change could also throw off health biomarkers, because the delayed eating group likely experienced a change in their biorhythm. While there was a trend for health markers to improve in the daytime compared to the delayed eaters, only HDL-cholesterol and insulin resistance improved significantly differently between groups. And just because insulin sensitivity was worse in the morning, this does not mean it was worse across the day on average. The researchers reported the biorhythm of blood sugar didn't significantly change as a result of the eating times, but if you look at the graph below, you can see the peaks and valleys in the two groups almost turned into polar opposites. Unfortunately, the researchers did not report the total area under the curve.




Interestingly, the delayed eating group also seemed to have an easier time sticking to their eating window. They reported significantly fewer eating events outside the planned times ($p$ = 0.05). In other words, they were more compliant with their diets. The timing of eating did not alter the circadian phase or amplitude of central clock markers (plasma melatonin and cortisol), nor sleep efficiency, indicating late night eating does not harm your sleep. However, the delayed eating group did report going to bed about 25 minutes later, probably because they still had to eat their last meal close to bedtime and wrap up their day before going to bed. This caused them to sleep on average 20 fewer minutes during the study. The reduced sleep could have partly explained the trend for worse health biomarkers in the morning for the late night eating group.

Overall, this study supports that under well-controlled conditions, eating late at night is not a problem for your body composition.

If you recall from the protein module, several studies have found that adding a late-night serving of protein has similar body composition effects as an earlier serving of protein, and pre-bed protein consumption may even benefit lean body mass according to some research. These findings are hard to reconcile with an inherently fattening effect of eating late at night. Given that non-overweight individuals, especially strength trainees experienced with calorie tracking, are more likely to accurately report their energy intake than overweight women on a novel diet, it's unlikely eating late at night will inherently harm your progression or health in any way, at least if the meals are high in protein.

## Circadian rhythm carbohydrate timing

Does it matter at which time of day we eat our carbs? We previously discussed that the idea that late night snacking makes you fat is a myth when you control for energy intake. Some people argue that it's even beneficial to eat most of your carbs later in the day after your workouts. John Kiefer popularized the idea of 'carb backloading', which means you consume most of your carbs later in the day, usually at night even. In support of this, [Sofer et al. (2011)] showed that the timing of carbohydrate can significantly impact body composition changes in diets with the same macronutrient composition. Eating carbohydrates mostly at dinner compared to spread across the day had several positive health effects.

- Greater weight loss with a trend for greater decreases in abdominal circumference and body fat percentage.
- A greater decrease in fasting insulin levels with a trend towards improved insulin sensitivity and fasting glucose levels (likely better carb tolerance).
- A greater increase in HDL ('good') cholesterol.
- A greater decrease in tumor necrosis factor-α (TNF-α), a marker of inflammation, with non-significantly greater improvements in the other inflammation markers as well (interleukin-6 (IL-6) and C-reactive protein (CRP)).

All of the health and nutrient partitioning related variables could simply be the result of the greater fat loss, since the subjects were overweight. However, the study also found that the circadian rhythm of the 2 hormones leptin and adiponectin changed as a result of the carbohydrate timing. There was a trend for a lower reduction in leptin levels in the carbs-at-night group and in this group adiponectin levels actually increased as a result of the diet. Normally leptin and adiponectin decrease in proportion with fat loss, since they are secreted by adipose tissue (fat), so it must have been the carb timing that altered their levels. Leptin and adiponectin are very beneficial hormones for fat loss. Leptin is a strong appetite suppressor and adiponectin can improve carb tolerance, inflammation, energy expenditure, nutrient partitioning and satiety, especially together with leptin. So the more your body produces of these hormones, the easier it is to lose fat, generally speaking. And indeed, the late-carb eating subjects were less hungry during the study.

Moreover, the daily secretion pattern of leptin and adiponectin changed. Leptin levels were higher at daytime compared to at breakfast and in the evening. Adiponectin levels also primarily increased at noon and the afternoon. Both levels decreased in the evening with a spike in ghrelin levels (‘the hunger hormone’). The authors noted this pattern of hunger hormones may improve dietary compliance, because hunger levels coincided with the large dinner. So by consuming your carbohydrates mostly at dinner, you may synchronize your appetite’s circadian rhythm better to your meal times, whereas when you eat your carbohydrates throughout the day, you may end up hungrier throughout the day. For many people it can also be inherently beneficial to be hungry during daytime hours, as most people are occupied with work at those hours.

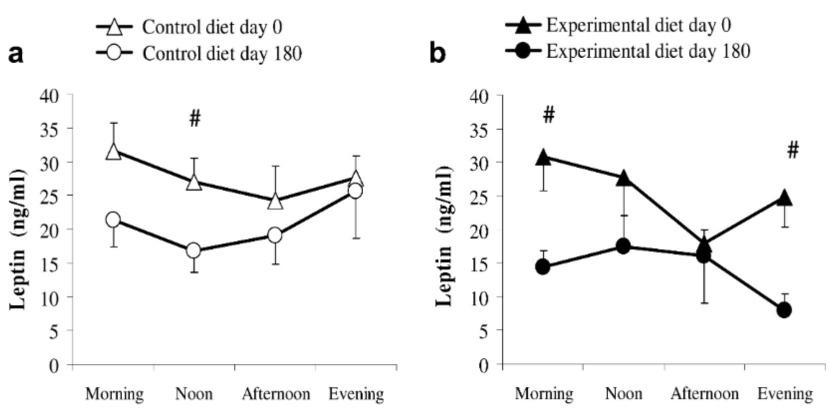



**Figure 1** Effect of diets on leptin’s diurnal curves. Mean ± SE on day 0 and on day 180 in the control (a) and experimental (b) groups. #$p = 0.023$ and $p = 0.021$ comparing day 0 and day 180 for the experimental group ($n = 18$) by $t$-test in the morning and in the afternoon respectively. #$p = 0.042$ comparing day 0 and day 180 for the control group ($n = 21$) by $t$-test in at noon. All data were log-transformed before analysis.

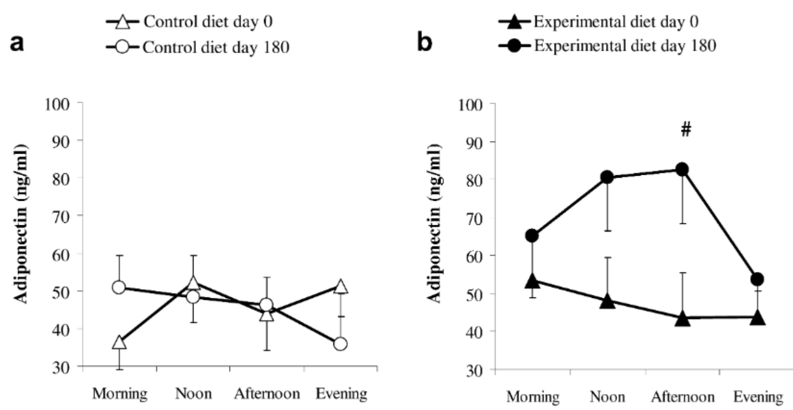



**Figure 3** Effect of diets on adiponectin's diurnal curve. Mean ± SE on day 0 and on day 180 in the control (a) and experimental (b) groups. #$p = 0.044$ comparing day 0 and day 180 for the experimental group ($n = 18$) by $t$-test in the afternoon. All data were log-transformed before analysis.

While these results are promising, other research has not supported carb backloading. Alves et al. (2014) found that consuming a high-protein dinner and high-carbohydrate lunch led to better fat-free mass retention with equal fat loss compared to a macro-matched diet with the high protein intake at lunch and the high carbohydrate intake at dinner.

And if you'll recall, Vlahoyiannis et al. (2024) compared 3 diets in trained individuals doing strength and endurance training. The diets had the same total macronutrient intakes but differed in how late they consumed many of their carbs.
1) No carbs anymore after their evening workout.
2) 40% carbs after their evening workout with a low glycemic index (GI).
3) 40% post-workout carbs with a high GI.

After 4 weeks, there were no significant differences between the groups in fat loss, fat-free mass gains or any physical performance indicator, including 1RMs. Notable study limitations include its short duration and body composition assessment by bioelectrical impedance (BIA) and skinfold calipers.

Even if carb backloading doesn't inherently improve our body composition, the potential reduction in hunger from carb backloading can be valuable. Some other research supports that high-carbohydrate breakfasts increase total daily ad libitum energy intake [2]. There seems to be minimal compensation for carbohydrate intake at breakfast. However, these findings are mostly based on highly processed carbohydrate sources, notably bread, which are inherently easy to overeat on. Fruit and vegetables are unlikely to be problematic.

It's worth trying to consume most of your carbs in the part of the day after your workouts to see if it helps with appetite management. Research does not support any exact distribution of carbs throughout the day, so in practice, you can often scale carbs with protein with up to 50-100% higher intakes in the post-workout meals of the day compared to the pre-workout meals, e.g. for a total daily carb intake of 500 g, an advanced trainee may consume them over 4 daily meals as follows.

Meal 1: breakfast 100 g
Meal 2: lunch/pre-workout 100 g
Meal 3: afternoon/post-workout 150 g
Meal 4: dinner/evening 150 g

## Circadian rhythm fat timing

Unfortunately, there is a major scarcity of research on the effects of fat timing. Based on the research we have, fat appears to be the least time sensitive macronutrient. Its absorption is slow and relatively unaffected by the circadian rhythms of insulin and glucose. The research discussed in the previous topics also generally shows that the effect of carbohydrate or protein timing still apply even when fat timing was also altered. This indicates that when you consume your fats in the day is relatively unimportant.

For example, Jakubowicz et al. (2012) found that groups with a high-carb or a high-fat breakfast lost just as much fat and weight. However, the high carb-breakfast group was more satiated after breakfast and across the study period as a whole.
An important confounder in this study is that the high carb group consumed more protein and calories at breakfast, as you can see in the table below, though they consumed less protein in total.

Another confounder is that with the very low carb intake in the high fat breakfast group, they almost certainly didn't consume enough fiber. Given that we know how important fiber, calories and protein are, specifically at breakfast for overweight individuals (see the course sections on fiber and intermittent fasting), this study cannot tell us much, but the timing of fat is probably not as important as that of carbs.

Table 1.
Diet composition by treatment assignment and sex.

| | HCb Women | | | | LCb Women | | | |
|---|---|---|---|---|---|---|---|---|
| | Kcal | gCh (%) | gProt (%) | gFat (%) | Kcal | gCh (%) | gProt (%) | gFat (%) |
| Breakfast | 600 | 60 (40) | 45 (30) | 20 (30) | 300 | 10 (13.3) | 30 (40) | 16 (48) |
| Lunch | 500 | 10 (8) | 70 (56) | 20 (36) | 500 | 10 (8) | 70 (56) | 20 (36) |
| Dinner | 300 | 8 (10.7) | 45 (60) | 10 (30) | 600 | 16 (10.6) | 90 (60) | 20 (30) |
| Total | 1400 | 78(19.6) | 160 (48.6) | 50 (32) | 1400 | 36 (10.6) | 190 (52) | 56 (38) |
| | | | | | | | | |
| | HCb Men | | | | LCb Men | | | |
| Breakfast | 600 | 60 (40) | 45 (30) | 20 (30) | 300 | 10 (13.3) | 30 (40) | 16 (48) |
| Lunch | 600 | 12 (8) | 84 (56) | 24 (36) | 600 | 12 (8) | 84 (56) | 24 (36) |
| Dinner | 400 | 11 (10.7) | 60 (60) | 20 (30) | 700 | 19 (10.6) | 105 (60) | 23 (30) |
| Total | 1600 | 83 (19.5) | 189 (48.7) | 64 (32) | 1600 | 41 (10.7) | 219 (52) | 63 (38) |

HCPb = high carbohydrate and protein breakfast diet. LCb = low carbohydrate breakfast diet; gCh (%) = grams of carbohydrate and %; gProt (%) = grams of protein and %; gFat (%) = grams of fat and %.

Since there's also no theoretical rationale to consume your fat intake at any particular time, research does not support any particular timing of fat intake. You can consume your fats whenever you want to consume calories.

## Combining fats and carbs?

In the above sections you learned that carbohydrates and fat may have better nutrient partitioning at different times of day. Upon realizing this, some people take this to extremes and suggest we should never combine fats and carbs in the same meal. Should you? Based on the course contents thus far, you should be able to answer this.

The answer is you should absolutely not completely separate carbs and fats from each other in your meals. Dissociating carbs from fats in your meals does not result in greater fat loss than consuming all 3 macronutrients within each meal. There are in fact several good reasons why you want to combine all 3 macronutrients in each meal.

- As you learned in the course topic on protein, certain whole foods like milk can have synergistic nutrient compositions that make the whole food more effective at increasing protein balance than you would expect from its macronutrient composition.
- As you learned in the course topic on human metabolism, balanced meals increase your metabolism (DIT) more than you would expect based on their macronutrient composition.
- Dietary fats and fiber can both improve the digestion and absorption of other nutrients.
- Plus, we have the evolutionary argument. Many whole foods have all 3 macronutrients. Not metabolizing such foods optimally would be a hugely disadvantageous trait that should be eliminated from the gene pool via natural selection.

So nutrient timing isn't a matter of excluding certain macros at certain times of day. It's about the ratios. Circadian rhythm carbohydrate timing doesn't require you to completely avoid carbs in the morning and save all your carbs for the later part of the day. It's about the macro ratios in your meals and the distribution of your macros across the day.

The myth that you should not combine carbs and fats in the same meal probably originates from people overeating on high-carb, high-fat foods. As we'll discuss in the course module on ad libitum dieting, such foods are generally highly palatable and easy to consume a lot of calories of. This is not a physiological concern, however, but a psychological one.

## Take-home messages

- It is best to train at the time of day when your performance is highest. This is normally the afternoon or early evening.
- If you can't train at the physiologically optimal time, meticulous caffeine use and a consistent biorhythm are extra important.
- Intermittent morning fasting does not have any special effects on your metabolism, hunger or body composition for most people, independent of energy balance.
- Intermittent fasting might decrease spontaneous physical activity levels and insulin sensitivity, so it is not advisable for individuals that are highly active in the mornings or for individuals with poor carb tolerance.
- Certain personality types do not have energy compensation after breakfast, which means fasting through the mornings is a highly convenient way to create an energy deficit. These individuals generally do not have any appetite in the morning.
- Overweight individuals, especially those with poor carb tolerance, generally lose more fat with a large vs. a small breakfast, probably in large part due to easier diet adherence.
- Alternate day fasting has a surprisingly good track record in research for fat loss, fat-free mass retention, appetite control and insulin sensitivity. Protein-sparing modified fast periods offer a way for strength trainees to obtain these potential benefits in addition to synchronizing their energy intake with their anabolic windows to possibly improve nutrient partitioning.
- Carb backloading may improve the biorhythms of leptin and adiponectin, leading to improved appetite control, nutrient partitioning and fat loss, so unless you need the carbs at a different time, it's advisable to skew carbohydrate intake somewhat towards the last meal or two before bedtime.

- Fat intake is probably not sensitive to timing considerations, so fat intake can go wherever calories are desired.
- You don’t have to actively avoid combining carbs and fats in the same meal. In fact, it is advisable to consume a whole-food-based diet with natural mixed meals.