PROGRESSION & PERIODIZATION

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Contents

For this module, it is essential that you've fully understood the course module on understanding muscle growth. If you aren't intimately familiar with the SAID principle, GAS theory or the morphological and neurological contributions to strength, you should revisit that topic before studying this one.

➢ Lecture

Periodization and progress

This lecture is optional: all contents are also covered in the text.

Progressive overload

After you set up an initial training program, you will need to start progressing on it. As your strength increases, the stress required for further adaptation inherently increases. To illustrate, if in any workout with an 8RM bench press your 8RM becomes your 9RM and you only do 8 reps again the next workout, that next workout is submaximal. If you keep training with your former 8RM instead of with your current 8RM, this workout will over time cease to become an effective training stimulus, as the weight becomes too submaximal. You may end up doing sets of 8 with your 20RM, which won't provide much stimulus for adaptation anymore. As such, for a training program to keep your muscles growing, it needs to impose continuously higher levels of stress on the muscle. This fundamental aspect of a good training program is called progressive overload.

Perhaps just as importantly as the physical need for progressive overload is the psychological need for a system to require you to train beyond your comfort zone. Without prescribed training program goals that require high exertion, many people will not train with maximal effort [2]. Having specified rep targets in your training is an effective way to force yourself to train with high effort. Monitoring and seeing progress over time is also highly motivational, thereby further increasing training effort.

The most straightforward and ideal method to increase training stress in a training program is to perform the same program with more weight. By increasing the absolute load to maintain the same relative training load (e.g. 8RM), you maintain the exact same relative training stimulus and you can keep forcing your body to adapt further. However, in practice an increase in weight often means you can no longer perform the same number of reps as before.

In this case, you can achieve progressive overload by performing more repetitions the next workout. At some point, you should increase the weight again, because progressing in reps by itself is not a sustainable method of progress. As you increase the repetition count, your training intensity decreases and the stimulus of your workout shifts towards the endurance end of the strength-endurance continuum. While going from 6 to 8 reps is very likely to increase your 1RM strength, going from 18 to 20 reps is not.

The training intensity at that point is too low for maximum strength progression or connective tissue adaptations. At some point it will also become too low for maximum muscle growth.

Some trainers argue that continued increases in load or repetition volume are not realistic, so you should not chase continued performance increases and instead implement progressive overload in other ways, such as by adding more sets or increasing the training density.

Here's a reality check. **If you're not getting stronger, you're almost certainly not getting bigger**. On an optimized training program, continued strength development should be expected, because neurological adaptations should practically always occur. Remember that strength development is the sum of morphological and neurological adaptations to a workout, chiefly muscle hypertrophy and increased neural efficiency. Since neurological adaptations are normally positive for strength, lack of net strength development strongly suggests negative morphological adaptations. So, if someone is losing weight and maintaining strength, they're likely losing muscle. The inability to implement progressive overload indicates a program is failing and you need to update it.

With the optimized programs you'll learn in this course, there should be only 2 scenarios where continued strength development is not realistic.

The first scenario is late-stage contest prep. Here you generally have an advanced trainee in energy deficit below the ideal nutrient partitioning range. While strength should still progress on relatively new exercises, all-time personal records or continued strength progression on exercises that have been in the program for a long time are not realistic. In fact, a truly elite level natural trainee will necessarily lose muscle mass and thereby strength during contest prep, because you can inherently maintain more muscle mass in the ideal body fat percentage range in part due to having higher anabolic hormone levels.

The second scenario is similar: elite level lifters. Here strength development is unlikely simply because any further muscular adaptation is unlikely. The more advanced a trainee and the closer they are to their genetic limits, the slower they can make further progress. Progressive overload will need to come slowly, because progress as a whole will come slowly.

For the vast majority of other cases, gaining strength on an exercise, measured as an increase in weight lifted for a given number of reps or an increase in repetitions performed with a given weight, should be the goal and is in fact necessary for long-term muscle growth. You should ideally be able to measure progressive overload in every workout for every exercise.

Other ways than load or repetition volume to implement progressive overload are generally misguided. They typically rely on an increase in training volume or novelty to induce extra stress under the mistaken belief that this causes new gains. **Progressive overload itself is not the cause of muscle and strength development. It is a**

measure that the previous workouts caused these adaptations, which is why you're now stronger. That you can now add weight to the bar does not guarantee you can lift more weight next time. You can only check that next workout. So progressive overload does not guarantee muscle growth or strength development. Progressive overload is the **measure** you're making good gains, not the inherent cause.

More importantly, not just any means of increasing the training stress is an effective method of progressive overload. Here are several ways you should generally not implement progressive overload.

1. Performing more sets

Performing more sets is a sure way to increase the training stress, but while you can happily keep increasing the number of sets you do for an exercise, without an increase in performance you have no idea if you're actually getting stronger or bigger. If you were stalling before on an optimized volume, it's very likely you're still plateaued now and all you're achieving is overreaching.

If you can perform more sets in a program and this improves your rate of progression, that means you were undertraining previously. If your training volume was already optimized, as you learned in this course, then increasing it even further will result in excessive stress, causing your body to be unable to recover and supercompensate before the next training session, thereby reducing rather than improving your rate of progress.

2. Increasing the training density

Density training has formed a niche following in the fitness community. The idea behind density training is that you perform the same training volume in a shorter and shorter amount of time as a method of progressive overload.

In practice, it's dubious if you can cut down your rest periods much without sacrificing training volume. De Souza et al. (2010) found that trainees progressively shortening their rest periods from 2 minutes to 30 seconds over an 8-week training program were unable to maintain the same training volume. These results were replicated by Souza-Junior et al. in 2011.

Even if you can reduce your rest periods while maintaining your training volume, this doesn't constitute true progressive **overload**. The stimulus for muscle growth is largely determined by total training volume, as you've learned. All other training program parameters are of secondary importance in that their effects on muscle growth are largely mediated by their effect on training volume. Specifically, as you've learned in the course module on rest intervals, the effect of your rest periods on muscle growth seem to be mediated entirely by training volume. It doesn't matter inherently how long you rest in between sets. It only matters how many reps your rest interval allows you to do and it's the total training volume that in the end determines the amount of muscle growth and strength development that will take place. If anything, you'd thus want to increase your rest intervals to achieve progressive overload, as this enables you to increase your total training load volume.

Even assuming we can maintain training volume with shorter rest periods and we call this progressive overload, achieving this does not mean you're getting stronger or bigger. The adaptations required to increase training density are like those for work capacity and they may be endurance rather than strength adaptations, such as increased capillarization, mitochondrial protein synthesis or improved oxygen delivery to your muscles and not necessarily myofibrillar protein synthesis or any improvement in muscle force production capacity.

Thus, an increase in training density does not tell you if your program is making you bigger or stronger.

3. Increasing time under tension (TUT)

Performing your reps more slowly can constitute effective progressive overload, but as per the course module on training tempo, it's generally not desirable to train with super slow tempos and it's very difficult to practically implement slow tempos. 4-second eccentrics on paper are commonly more like 2-second eccentrics in reality. Anecdotally, continually changing your repetition tempo over time can also mess with your technique, especially if you implement pauses or slow down the concentric.

4. Increasing the training frequency

An increase in training frequency does not in itself constitute progressive overload. While it may allow you to achieve a higher total load volume with an exercise, this is because you're performing the exercise in a less fatigued state, not necessarily because your previous workout made you stronger.

If the increase in training frequency was in fact beneficial to improve your gains, you should have done it already.

Plus, you can't keep increasing the training frequency, so it's not a feasible method of progression anyway.

5. Changing exercise

Switching to a different exercise should be a last resort in terms of progressive overload, because it effectively erases your load history. Anyone can get stronger on a new exercise due to the fast increase in neural efficiency when we learn a new movement pattern. The first few times you achieve progressive overload with a new exercise are thus good news, but they're more of a bare minimum sign your program is working than a reliable indication of muscle growth. If someone has never done single-leg squats before, getting them 10% stronger on this lift is easy and doesn't necessarily require any muscle growth. Improving an advanced powerlifter's back squat strength by 10%, on the other hand, is a strong indication they got bigger or at least the program was effective.

Practical application

Linear weight progression with a given repetition target is the ideal method of progressive overload for any exercise: you perform the exact same workout every time you're in the gym with the only difference that you're moving greater weights.

However, even when you've designed an optimal program for someone based on this course's guidelines, sooner or later they will stop being able to add weight to an exercise and perform the same number of reps with it as last workout. Linear weight progression becomes impossible. This happens long before the person has approached their genetic limitations.

When an exercise stalls is largely determined by the exercise's increment, the smallest amount of resistance you can add to an exercise. For example, if your cable stack moves up like 47, 54, 61, 68, etc. the increment is 7; if your smallest barbell plates are 2.5 lb, as is common, your increment for barbell exercises is 5 lb, assuming you don't want asymmetrical loading and add a plate only to one side.

Trainees beyond the novice level can typically not progress in strength at a rate of more than 2.5% per workout. Therefore, with a traditional 5 lb increment, it is only potentially realistic to expect exercises performed with more than 200 lb to progress linearly in strength without loss of repetitions across sessions. For example, barbell compound exercises like squats and deadlifts can typically progress linearly in weight reasonably well: you perform 300 lb x 5 reps one workout, then 305 lb x 5 reps the next workout. However, isolation exercises like lateral raises are extremely unlikely to progress linearly in weight with 5 lb increments. Going from 20 lb to 25 lb is a 25% rather than a 2.5% increase in weight, akin to trying to go from 300 lb instantly to 375 lb.

When adding weight and hitting your rep target from workout to workout is not realistic for an exercise, you can intermittently implement progressive overload by increasing the repetitions until you hit the rep target, before you progress further in weight. Progressing in reps within a certain rep range is equally effective for muscular development as progressing in load [2]. For example, you could go from 20 lb x 12 to 25 lb x 4 reps, then 5 reps the next workout, etc. until you reach 25 lb x 12 reps and then you go up to 30 lb.

Autoregulation

Traditionally, progressive overload is planned in advance in training programs: sets x reps x weight are programmed weeks or months in advance. Modern programs generally do not favor this approach anymore and prefer autoregulated progression. Autoregulated training programs result in greater strength development than training programs with predetermined weights x reps [2, 3, 4]. In fact, 'autoregulation' has become such a cool buzzword in the evidence-based fitness community that it has lost any concrete definition.

True autoregulation is a form of programming that automatically regulates a certain process. You can think of autoregulation as a system or a ruleset instead of a fixed prescription. The combination of progressive overload in reps and weight we discussed above is a form of autoregulation: you increase the weight when you hit your rep target, regardless of when this occurs. Until then, you progress in reps.

Other examples of true autoregulation have already been discussed in this course, such as the muscle-specific hypertrophy method (autoregulates training program volume on a muscle-specific basis) and autoregulated rest intervals (autoregulates inter-set rest intervals based on subjective readiness to perform).

Autoregulation is an incredibly useful programming method, because it automatically individualizes the training program. As you've seen in the course topic on individualized program design, there is huge interindividual variability in many aspects of fitness. People differ significantly in how many reps they can do at a certain training intensity, how much rest they need for full recovery, how fast they can gain strength, etc. Autoregulating these factors in the program is thus preferable to the traditional fixed program prescriptions, which require arbitrary decisions, relying on averages or predicting future performance with improbable accuracy.

For example, many one-size-fits-all Powerlifting programs base the training of the next month on the person's current 1RMs. On a certain day, the program may call for 6 reps at 85% of 1RM. Most people can't do that with a true 85% intensity, but because this is based on last month's strength, this is the program's way of planning progression. Now, what if on this particular day you can't reach anywhere near 6 reps because your diet has been less than ideal? And what if yesterday you could have done it but the program called for a light workout?

Many coaches that have tested these programs are aware of these problems, so they often plan for a slow rate of progression to ensure almost everyone can achieve the program's planned rate of progress. However, this inherently also requires that almost everyone will make less progress than they could have on a more individualized, autoregulated program.

In addition to autoregulating your rate of progressive overload, it is also advisable to autoregulate your session to session repetition volume with a method called Autoregulatory Volume Training.

Autoregulatory volume training

In real life, progression in strength does not occur perfectly linearly, because while you can optimize your program's training stimulus, the resulting adaptation process may vary because of lifestyle changes. Specifically, recovery capacity can be compromised by consuming a less anabolic diet (e.g. alcohol, insufficient protein intake), sleep deprivation, a higher than normal exposure to stressors or a circadian rhythm disruption.

To deal with lifestyle fluctuations in recovery capacity, it can be useful to implement autoregulatory volume training (AVT). AVT is a programming method in which you only plan the weight and number of repetitions of the first set, e.g. 260 pounds for 8 reps, for a multiple set exercise. This first set is your ‘benchmark set’. The subsequent sets are ‘volume sets’. They’re performed with the same weight and proximity to failure, but you do not plan how many repetitions you’re going to do in advance. In fact, in principle you don’t even need to count your reps in these sets.

The purpose of AVT is to autoregulate training volume based on the difficulty of the first set. The more neuromuscular fatigue the first set induces, the lower the total volume for that session will be. If the first set had you bust out your tomato face to grind through the sticking point in the squat and left you feeling so lightheaded you wondered how you even managed to rerack the bar afterwards, then you will naturally perform fewer reps in the subsequent sets. In contrast, if the first set had you progress as planned with more left in the tank, then you will naturally perform more reps in the subsequent sets.

The result is that AVT normalizes the training stress over time to prevent overreaching yet also ensure a sufficient training stimulus.

Importantly, you should implement AVT at an exercise-specific level, which is highly preferable to the more common regulation of training volume at the whole-body level. As you’ve learned in the course topics on the physiology of strength training adaptations, structural balance theory and what neuromuscular fatigue really is, muscle fatigue is largely a local process and it makes no sense to take it easy on your biceps curls today because your quads haven't recovered yet.

Here's a simple example of AVT. Let's say we've got a novice lifter who can still put 5 pounds on the bar every squat session and perform 8 reps with that. He squats on Monday (because screw national bench press day) and Friday (because screw 'early weekend') with a volume of 3 sets. Last Friday he performed 200 pounds x 8, 7, 6 reps. Next Monday he was feeling frisky because he got laid for the first time in months and had slept like a baby that weekend. So he was very well recovered, he hit 205 pounds x 8 reps with ease and he managed to do 8 reps in the 2 subsequent sets as well. On Friday that week he was mildly sleep deprived and more stressed from the work week, so he hadn't recovered that well and it took everything he had to hit 210 pounds x 8 reps. In the subsequent sets he only managed 4 reps, which is fine, because the near-failure squat set induced a lot of fatigue already.

Another benefit of AVT is that individuals learn to mentally break free from the constraints of performing each set while counting the repetitions, which frees up attention to focus more on your exercise technique.

Physically, AVT can also increase force production throughout the set. During exercise with a defined endpoint, like a certain number of repetitions that you want to achieve, you will naturally pace yourself by holding back during the early part of the exercise. This is good for endurance and the achievement of the goal you have in mind in terms of quantity, but when you don't need to hit any specific performance goal, it can detract from the quality of the exercise in terms of muscle activation, exercise technique and force production.

One obvious caveat to the use of AVT is that it only works for serious, motivated strength trainees that have no problem pushing themselves and won't see not counting their reps as an excuse to slack off. If your idea of training intensely is having trouble reading Shape magazine during your leg extensions, AVT is not for you.

In sum, AVT normalizes the training stress of your program over time by autoregulating the training volume of your subsequent 'volume sets' based on the difficulty of your first 'benchmark set'. Not having rep targets during your volume sets allows you to focus on your exercise technique, improves force production and can help reduce performance anxiety to make your workouts more enjoyable.

Cybernetic periodization

Autoregulation is often confounded with what was once called cybernetic periodization, a form of flexible periodization that allows ad hoc program modifications based on how you feel during any workout. Cybernetic in this case refers to a programming hybrid of robotic/planned periodization with organic/flexible modifications. For example, when feeling poorly going into a workout, you may opt to make this a light training day even though it was planned as a heavy workout.

This form of cybernetic periodization is, however, not autoregulation by definition. Very conscious decision making is required, which is not true autoregulation.

Distinguishing between true autoregulation, cybernetic periodization and making on-the-fly programming decisions based on how you feel is important. True autoregulation is a highly useful programming concept. If you can autoregulate any process, that is almost always preferable over trying to plan it in advance or making arbitrary decisions because it automatically individualizes the program.

However, the usefulness of cybernetic periodization is far more debatable. Let's say you're not feeling like working out. Is this a sign you're best off taking a rest day? Probably not. In contrast to popular belief, motivation to train is not correlated with actual performance in either professional or amateur athletes.

How about if you don't feel recovered (whatever that means)? Researchers have studied Perceived Recovery Status (PRS) in various contexts. PRS has been found to correlate with the recovery of sprint performance, jump height and squat barbell velocity and creatine kinase (a marker of muscle damage). However, a correlation with recovery after a workout does not mean much, especially not at a group level average.

It doesn't take an autoregulatory genius to know that the day after doing 10 sets of squats, you're not fully recovered yet. And of course you can predict that each subsequent day, you're more recovered than the previous day. So even without internally sensing anything related to your neuromuscular readiness to perform, there should be considerable overlap – a correlation – between 'perceived' recovery and objective recovery. The practical question is: is the perception of recovery accurate enough to predict day-to-day changes in strength for an individual?

Zourdos et al. (2016) found that pre-training PRS scores did not consistently correlate with daily 1RM strength in well-trained powerlifters and weightlifters. Perceived recovery status thus did not signal objective readiness to train, which means it's arguably not useful in practice. Similarly, Wallace et al. (2019) found that strength-trained men were unable to subjectively sense which workouts were most fatiguing. Objective performance and neuromuscular fatigue differed between some of the workouts, but the lifters did not report different PRS scores for these workouts. The lifters were thus unable to determine which of the workouts were more objectively fatiguing. Barsuhn et al. (2024) also found no significant differences in PRS between groups maintaining their habitual training volume vs increasing it by 30% or 60%. The participants were well-trained lifters squatting about double bodyweight.

In arguably the most relevant study, Bartolomei et al. (2024) investigated if serious lifters – half were competitive strength athletes – could improve their muscular development by autoregulating their training volume. If they felt well-recovered, they added up to 2 sets per exercise, and they subtracted up to 2 sets per exercise if they felt underrecovered or very tired. This group was compared to a control group that performed the same program with a fixed training volume. They trained 5x per week, so the total potential volume adjustment was very large: about half of their total volume. After 10 weeks, there were no significant differences between the groups in strength gains (squat and bench press 1RM and isometric force), power (bench throw and jumping) or muscle size (biceps, traps and quads muscle thickness). Perceived recovery status evidently does not align with our objective neuromuscular recovery or strength and adjusting our training volume based on how recovered we feel does not seem to improve our gains.

Our perceived recovery is a cognitive-emotional evaluation of recovery, not an internal monitor of our contractile tissue status. The few physical sensations we can directly monitor, such as muscle soreness, still don't consistently correlate with objective markers of muscle damage, as you learned in the module on understanding muscle growth. The psychological nature of PRS makes it susceptible to placebo effects. For example, cold plunges and cryotherapy in general often hamper or do not affect post-exercise muscular recovery and performance, yet many people report that in comparison to no intervention, cryotherapy improves *subjectively perceived* recovery (see course module on injuries for more details). That's likely why cold plunges have remained relatively popular despite clear evidence that they're often not just wasted time and effort but even harmful for our gains. When researchers compare cryotherapy to a placebo intervention, any differences in recovery typically disappear, indicating the improvement in perceived recovery in other uncontrolled cryotherapy studies was a placebo effect. Perceived recovery status also increases significantly after the consumption of caffeine, despite caffeine obviously not improving recovery acutely. It just makes you temporarily feel better. Similarly, in a study on the relation between PRS and sprint performance, PRS only correlated with sprint performance recovery when the post-warm-up PRS scores were used: PRS scores before the trainees warmed up did not significantly corelate with performance. Many people feel fatigued when going to the gym sometimes, but once they've done their warm-up, they feel ready to rock: the fatigue they felt was mental, not physical.

The core idea that our subjective feelings accurately represent our physical readiness to perform is flawed. Mental fatigue is very similar in nature to boredom or unhappiness, as we'll discuss in the module on dietary adherence. As the name implies, mental fatigue is mental, not physical. Mental fatigue does not impair neuromuscular functioning or maximal force output; however, it does increase perceived effort during exercise [2, 3, 4, 5]. If you're not highly motivated to exercise, the increased perception of effort can make you stop tough work sets earlier and thereby reduce your training volume. The most mentally demanding types of exercise are most vulnerable to mental fatigue, in particular (strength-)endurance exercise and highly complex exercises like squats. A 2022 meta-analysis found that significant, acute mental fatigue, such as from 30 minutes of complicated, boring 'puzzles' (Stroop tests), can reduce total repetition volume during strength training. All studies in which performance was impaired included multiple sets of medium-to-high rep back squats (max. 70% of 1RM) or low-intensity strength-endurance exercise (max. 60% of 1RM). In contrast, a 2017 systematic review found no effects of mental fatigue on maximal strength, power or anaerobic work in general, only on endurance exercise.

Many people have a limit to how much mental fatigue they can withstand, which depends on their self-control and motivation. For example, one study found that national level Olympic weightlifters did not have any impairment of their lifting performance after **24 hours** of sleep deprivation, despite obviously *feeling* far worse. Giving up on some arbitrary performance task for a study you 'have' to do is different from not meeting the performance target that you set for yourself in your own training. Training experience also seems to reduce the effect of mental fatigue, likely because it shows you what your body is capable of. Experience makes you more comfortable with fatigue and makes you aware of what your performance *should* be. Filipas et al. (2020) found "4 weeks of endurance training increased tolerance to mental exertion in untrained participants during a subsequent [workout]. This finding suggests that the ability to tolerate mental exertion is trainable".

Another reason mental fatigue should not be as much of a factor in your workouts as in the laboratory experiments is that mental fatigue is very acute. As we'll discuss on the module on program adherence, it's easy to undo mental fatigue by doing something you enjoy. In laboratory experiments, participants performed the mentally fatiguing activities *directly* before their workout.

More generally, basing your program design on subjective sensations is highly prone to the introspection illusion. We naively often assume that how we feel is a perfect representation of what goes in our bodies, but psychological research has found that's not the case at all. We are only aware of a tiny fraction of what goes on in our bodies and it's mainly higher-order cognitive processes that enter into conscious thoughts at all, such as language, active decision making and mathematics. We cannot feel our blood pressure, how well our liver functions or which muscles exactly we activate when throwing an object. To make rational decisions about program design, it's best to rely primarily on facts instead of our feelings.

Heart rate variability

Heart rate variability (HRV) has become somewhat popular to autoregulate how long you should rest in between workouts, or more generally how to manage fatigue. The idea is that your HRV is an indication of your systemic stress tolerance: if your HRV hasn't returned to baseline yet, you haven't recovered.

This may have some validity for endurance training, and it's nice that it's an objective and quantifiable metric, but it's logically hard to see what the variability in your heart rate has to do with the status of your muscle tissue. Research finds HRV or heart rate in general does not correlate well with performance or other measures of recovery status [3] in strength trainees, that there is large day to day variance in HRV even when performance doesn't change and that the correlation between HRV and performance differs considerably per individual and depends on which posture you're in when measuring your HRV. In other words, HRV is an outright terrible measure of recovery status.

De Oliveira et al. (2019) compared a group training with a fixed 48-hour period between strength training workouts with a group that trained when HRV had returned to baseline (specifically the root mean square of successive R-R intervals differences (RMSSD)). There was no difference in muscle growth (CSA) or 1RM strength development between groups. The group without HRV actually gained non-significantly more strength (42% vs. 30%).

In conclusion, strength trainees generally don't need to bother with measuring their HRV. It's about as informative as looking at your horoscope to see if it's time to squat.

Velocity

If we cannot predict how well we've recovered or how well we'll perform before we go to the gym, perhaps we can infer it from our warm-up? A famous anecdote on this is that a certain powerlifting champion used to go to the gym and do some warm-up sets on the bench press. Then he'd sometimes just go home afterwards, as he wasn't feeling it. The idea is that his explosiveness was a predictor of his 1RM strength. If he wasn't feeling explosive, he supposedly wasn't strong that day and may have needed more recovery time.

Cool story, but does it actually work? While there is some support for vertical jump height as a predictor of subsequent strength performance, most scientific research shows movement velocity is a poor predictor of subsequent performance (recovery) [2, 3]. It would theoretically make sense that movement velocity could predict maximal force output, as movement velocity and proximity to failure are strongly correlated, as you learned in the module on understanding muscle growth, but there are several problems with this method.

- The further away from failure you are, the weaker the relation, so you need to train with heavy weights to accurately predict your 1RM.
- The relation between velocity with submaximal weights and maximal strength differs per individual and per movement.
- Warming up itself can also increase maximal force output, so the test changes the outcome of the test.

Overall, even if you have the equipment and the calibrations in place to monitor your exercise velocity, it doesn't seem to be very useful to know. The potential for nocebo effects may offset any marginal benefits you get to autoregulate your program.

To recap, there's no good way to predict performance or progression, so it's best to autoregulate your progression based on objective data. Autoregulatory volume training autoregulates your workout's training volume based on your level of neuromuscular fatigue. This neuromuscular fatigue is different from mental fatigue. So what exactly is neuromuscular fatigue then? Only when we understand physical fatigue, can we learn how to manage it.

What is fatigue?

Most people think of fatigue as a feeling without a concrete definition of it. In exercise science, we have a very objective and quantifiable definition of muscle fatigue. Muscle fatigue is a temporary decrease in maximum force production capacity due to changes within the neuromuscular system that occur in response to muscle use. Basically, muscles lose functionality when they are heavily used. In practice, you can readily observe fatigue as a loss of strength after stressful exercise. After a heavy set of 8 reps, next set you may only manage 5 reps. That's fatigue.

While you may intuitively think of neuromuscular fatigue as 'wear and tear', fatigue is more generally a disruption of one or several processes involved in carrying out the performed task, causing them to become a limiting factor and ultimately resulting in task cessation. Fatigue is highly task-specific: you can become very fatigued at one activity or in one part of your body but not another.

Neuromuscular fatigue can have two origins: central and peripheral, as illustrated below.

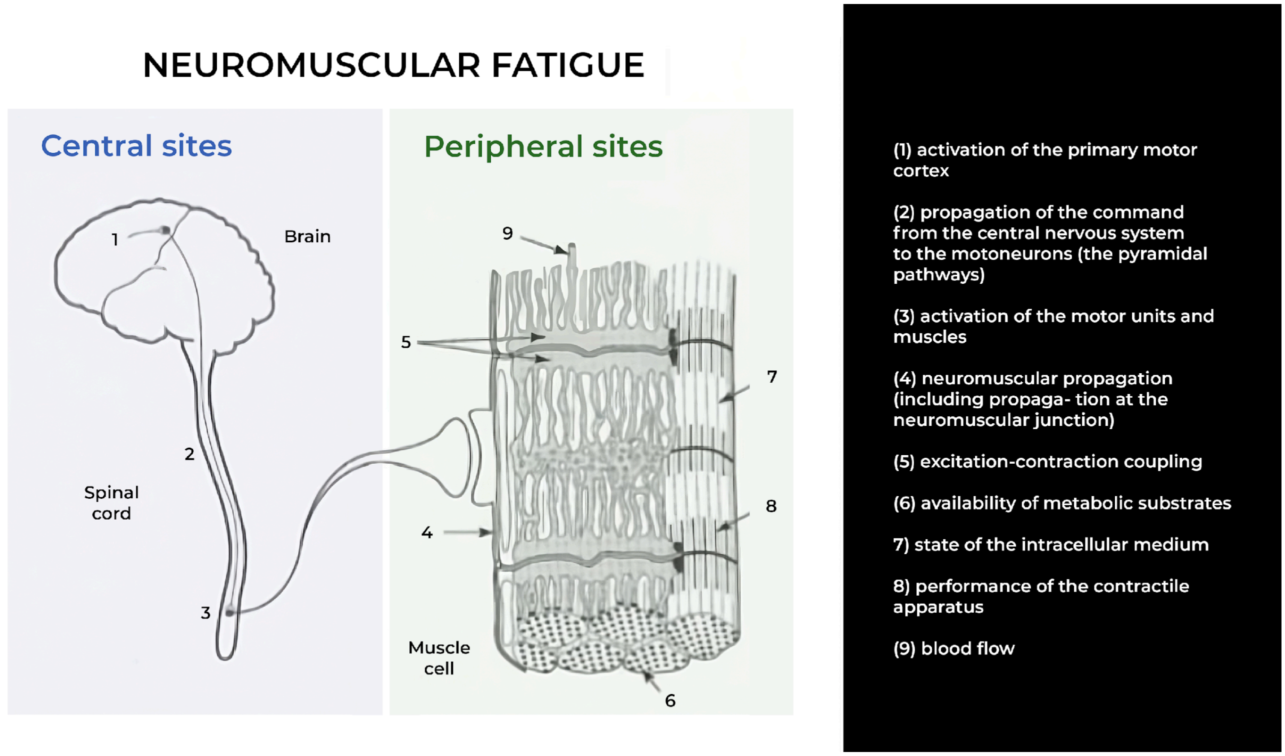


Figure adapted from [Boyas & Guevel (2011)]

Peripheral fatigue

Peripheral fatigue, or local fatigue, is the more tangible kind of fatigue that occurs within your muscles. While intuitively you may think peripheral fatigue is primarily caused by damage to the muscle by 'wear and tear', actual damage to the muscle's morphological structure seems to be a relatively small cause of fatigue.

Instead, local fatigue seems to have 2 primary sources.

1. Disruption of the contractile process, leading to decreased force production by the muscle fibers. This primarily involves 2 factors.
    a. Impaired actin-myosin crossbridge formation, which weakens muscular contractions.

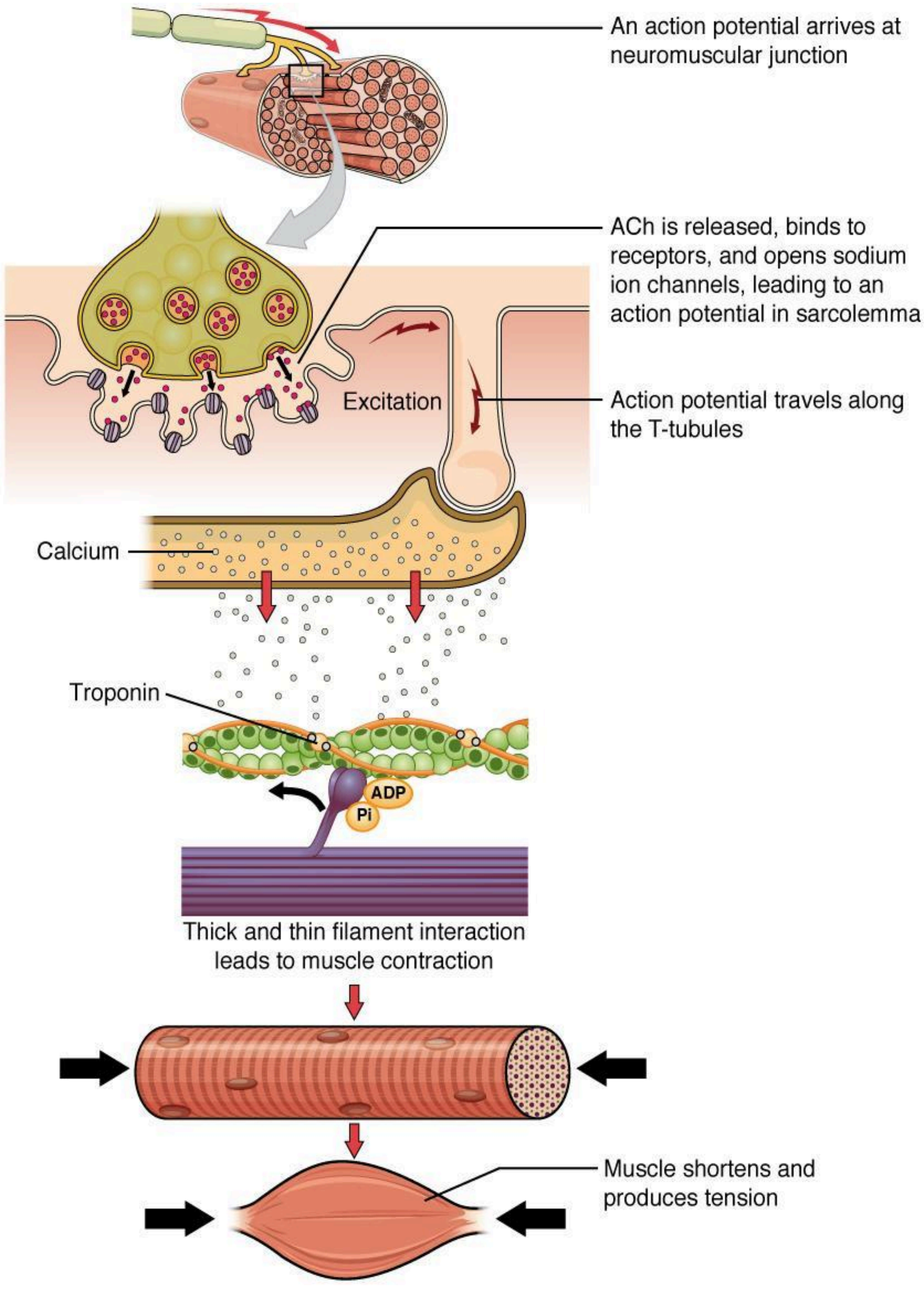
   b. Excitation-contraction coupling failure, which disrupts the process of muscle activation: the neural signal or excitation sent by the brain to the muscle is no longer effectively converted into a contraction.
2. Disruption of metabolic processes required to generate ATP, leading to decreased energy production.

Metabolic fatigue is often focused on, especially in the form of 'metabolic stress'. Before that the bro bodybuilding community simply spoke of 'the pump' and 'the burn'. Metabolic stress sounds more scientific, but it actually does not have a precisely quantified definition in exercise science other than that it refers to the accumulation of metabolites and the deprivation of oxygen in tissue (hypoxia) during exercise.

Many textbooks incorrectly propose that lactic acid is the primary source of fatigue during high-intensity exercise. Lactic acid is said to cause intracellular acidosis, which interferes with calcium release and reduces the ability of your muscles to contract. You feel this supposed 'lactic acidosis' as the burn. However, this theory is incorrect on multiple fronts.

First, muscles barely produce any lactic acid. They produce lactate, which is a weak base, not an acid. The associated acidosis seems to be mainly caused by the accumulation of hydrogen ions (H^+). Lactate is not a source of muscle fatigue; lactate is actually a buffer against metabolic stress, as lactate is a fuel source for many tissues, including muscles. Muscles can burn lactate as fuel via oxidative phosphorylation in their mitochondria, or they convert it to glucose via the Cori cycle (gluconeogenesis).

Second, acidosis per se is not consistently related to muscle fatigue in the first place. The exact causes of metabolic neuromuscular fatigue are still being explored, but research points to several metabolites, including inorganic phosphate (P_i) and reactive oxygen species (ROS). Phosphate may bind to calcium, which prevents the calcium from initiating cross-bridging between actin and myosin to produce muscular contractions. Calcium ions (Ca^{++}) are essential for muscle contraction, as illustrated below. However, calcium accumulation within muscle cells during exercise can also cause muscle fatigue and even muscle damage. A strong case also remains for the role of potassium and other electrolytes to interfere with calcium signaling and release.



Contraction of a muscle fiber: A cross-bridge forms between actin and the myosin heads, triggering contraction. As long as Ca^{++} ions remain in the sarcoplasm to bind to troponin and ATP is available, the muscle fiber will continue to contract. [*Source: BC campus*]

Despite the many flaws in the traditional explanation of ‘the burn’, since lactate’s concentration is correlated with the amount of metabolic stress and fatigue, it can be used as an indicator of metabolic muscular fatigue, even if it is not the cause of it.

Regardless of the exact mechanisms, the result is there is disruption of the contractile processes during high-intensity exercise, which causes us to become unable to keep lifting a given weight. Accumulated metabolites from high-intensity exercise, including hydrogen ions ($H^{\pm}$) and inorganic phosphate (P_i) are generally cleared within a matter of minutes, so most metabolic fatigue should not last longer than 5 minutes.

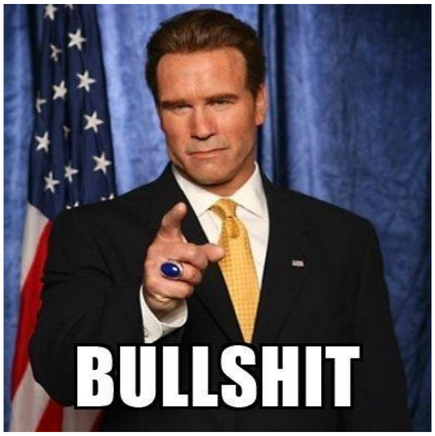
Central fatigue

Central fatigue is a topic riddled with broscience, often conflated with feeling tired. Let’s look at what central fatigue is, what causes it and what this means for your training.

What is central fatigue?

Central fatigue is fatigue that affects the whole body. It’s a systemic problem that reduces performance in every body part. A primary purported source of central fatigue is central nervous system (CNS) fatigue. As the name suggests, CNS fatigue occurs in the central nervous system: the brain and the spinal cord. If your CNS is fatigued, it has trouble activating your muscles. So even while your muscles are capable of producing a lot of force, they may not achieve this potential, because the CNS isn’t giving them the proper instructions. More formally, central fatigue occurs when the net excitation supplied by the motor cortex to motor neurons decreases. In other words, CNS fatigue causes a decrease in voluntary muscle activation.

A once popular theory called the Central Governor model (CGM) of fatigue posits that central fatigue is the only source of true fatigue, but this has been thoroughly debunked. The classic example of proof of the Central Governor in action is the ability of marathon athletes to increase their pace at the end to sprint to the finish, despite major peripheral fatigue. However, this final sprint can be explained by the intensity-specificity of fatigue, such as the different physiological demands of sprinting compared to lower intensity running (e.g. different substrate use). It can also be explained by psychological factors, such as increased motivation to reach the finish. Another example that fatigue is intensity-specific is post-activation potentiation: as you learned, it's possible to induce fatigue with high-intensity exercise that *improves* performance during subsequent lower-intensity training. Unsurprisingly, the Central Governor model has been extensively criticized, because it doesn't address task dependency. It is a well-known and easily-observable finding that fatigue is task-dependent. As you complete several sets of biceps curls, your biceps fatigue but your quads generally do not and your performance on subsequent leg extensions is generally unaffected. Even in exercises involving the same muscle groups, it's readily observable that fatigue is very task-specific. So next time somebody brings up the Central Governor Model of fatigue, send them this picture of the one true governor of bodybuilding.



CNS fatigue is often conflated with central fatigue in general, but paradoxically, not all CNS fatigue is central. Fatigue specific to motor neurons is technically CNS fatigue, because the cell bodies of motor neurons lie in the spinal cord even though their axons extend out of the CNS into the peripheral nervous system and they have regional effects. Motor neurons send activation signals originating from the brain to our muscles. Reduced activation of a motor neuron only affects the muscle fibers it innervates (together forming the motor unit). It does not affect other body parts. Thus, reduced motor neuron excitability is a form of CNS fatigue with purely local effects in a single muscle.

Scientists often measure central nervous system fatigue by comparing the ratio of voluntary to involuntary muscle activation. Involuntary muscle activation can be tested with electrical stimulation. One of the advances in cognitive neuroscience is transcranial (trans = through, cranium = skull) magnetic stimulation (TMS). With an electrical device, researchers can stimulate certain areas of the brain with an electrical current. They can, for example, let you move your hand by putting the device on a certain spot on your brain. It's a weird sensation to feel your body move without being in charge of it. By testing involuntary activation, we can see if the brain is activating your muscles as well as it could. The central activation ratio (CAR) basically gives us the gap between how strongly a muscle is physically capable of being activated (with TMS) and how much of that the CNS achieves voluntarily. We can also measure central fatigue by directly looking at the signal sent by the motor cortex of the brain to your muscles, formally corticospinal excitability. One measure of this signal is the motor-evoked potential (MEP). A decrease in MEP means there is central fatigue, as the CNS isn't directing the muscle 100% anymore. Related measures of inability of the central nervous system to activate your muscles are intra-cortical facilitation (ICF), short-interval intra-cortical inhibition (SICI) and long-interval intra-cortical inhibition (LICI). A more contentious measure of CNS fatigue is simply measuring voluntary muscle activity, but voluntary muscle activity can also be reduced by peripheral factors or reduced motivation, so it's not necessarily evidence of CNS fatigue. In fact, all the above measures are somewhat contentious, as there's evidence that maximal voluntary muscle activity is inherently lower than the level of muscle activity that can be electrically evoked. Practically speaking, the most relevant measure of central fatigue is whether performance in unrelated body parts is affected. For example, if squats reduce force production of your triceps, that's indicative of central fatigue.

What causes CNS fatigue?

CNS fatigue is commonly said to occur from exercise with large neural demands, namely high-intensity exercise. It sounds very plausible. The higher the percentage of 1RM you're training with, the more work the CNS has to do, the more fatigued the CNS gets, right?

Wrong. It's completely the other way around. Central fatigue is greater after low- than high-intensity endurance exercise [2]. The research that finds CNS fatigue from strength training is often based on artificial training protocols that are more like endurance than strength training. As an example of a 'strength training' research that found significant central fatigue, Smith et al. (2007) studied a *70-minute* biceps contraction. A similar study found central fatigue after a *4-minute* dorsiflexor contraction. Just like with endurance training, central fatigue during isometric contractions increases with exercise duration [2], so while these studies are evidence of the existence of central fatigue, they're hardly informative of what happens during practical strength training workouts where muscular contractions typically last seconds, not minutes.

Marshall et al. (2015) used somewhat more practical contraction times of 30 and 60 seconds with intensities of 40% and 80% of maximal torque during isometric leg extensions in trained men. Neither workout decreased central motor output. In fact, there was *upregulation* of central motor output, presumably to offset the peripheral fatigue. The 40% intensity resulted in the greatest peripheral (muscle) fatigue as well as the greatest CNS upregulation.

In a more practical training setting, Latella et al. (2017) compared the effects on the nervous system of a 'hypertrophy workout' of 3 sets of 12 reps with 1 minute of rest between sets with a 'strength workout' of 5 sets of 3 reps with 3 minutes rest between sets in the leg extension machine. All neuromuscular fatigue was peripheral in nature after both workouts. CNS functioning as measured by ICF, SICI and LICI did not change at all. MEP again showed *upregulation* of central motor output, which the researchers called a compensatory mechanism to offset the muscular fatigue. The upregulation was acute: it was only significant immediately post-workout – a whopping 250% of baseline – and then dissipated over the course of 6 hours.

In conclusion, the common theory that higher exercise intensities induce greater central nervous system fatigue is a myth. It's rather the duration or volume of exercise rather than the intensity of exercise – essentially the opposite – that causes central nervous system fatigue. Since strength training is by nature high intensity training, it does not suffer much from central nervous system fatigue. In fact, there's now clear research showing at least 80% of neuromuscular fatigue during exercise is peripheral in origin [2, 3] and it's even debated if central fatigue has *any* meaningful contribution to high-intensity resistance training. For example, Thomas et al. (2018) found no significant central fatigue after *10 sets* of squats. A 2021 systematic review and meta-analysis of the literature by Behm et al. concluded central fatigue is generally 'trivial or absent' for strength training and only significant for endurance training. So any contribution of the CNS to fatigue is likely in the motor neurons, which is local fatigue, not central fatigue.

[Howatson et al. (2016)] is perhaps the most telling example of how overrated CNS fatigue is for strength training. They studied the neuromuscular recovery of elite athletes. The guys were squatting well over 8 plates (190 kg) and running the 100 m in 10.44 seconds. For reference, the world record is 9.58 seconds, set by Usain Bolt in 2009. The ladies were rocking an over 4 plate squat (108 kg) and running the 100 m in 11.73 seconds. The world record for women is 10.49 seconds, set by Florence Griffith-Joyner in 1988. These elite athletes then performed one of their typical workouts, consisting of 4 sets of 5 reps for the back squat, the split squat and the push press: a total of 12 sets of heavy compound work.

There was no central fatigue. Voluntary central nervous system activation did not decrease from pre- to post-workout and was still stable 24 hours later. Of course, there was significant neuromuscular fatigue, as evidenced by reduced contraction power of the muscles (MVIC) and an insignificant trend for lower jump height (CMJ). There was also metabolic stress, as measured by an increase in blood lactate. But the nervous system had no trouble activating the muscles. The muscles were simply fatigued themselves, presumably from the damage of the workout and the metabolic stress. The fatigue was local, within the muscles, not in the central nervous system.

It makes sense that the central nervous system doesn't easily fatigue. Our brain is more similar to a computer than a muscle. It doesn't have fibers that tear with use, it doesn't accumulate metabolic waste products and it doesn't have energy substrates that easily get depleted. It's not well-established that central fatigue exists at all. The vast majority of what was previously thought to be central fatigue can now be explained by local fatigue. Central 'fatigue' may occur via other mechanisms though. For example, ammonia may cause CNS fatigue, as it is neurotoxic: muscular ammonia production during exercise can leak into the blood and cross the blood-brain barrier can cause neurotoxicity [2, 3].

Local CNS fatigue is much more prevalent. For example, Latella et al. (2016) looked at the nervous system's response to 5 sets of 3 biceps curls at 94% of 1RM. There was a whopping 46% decrease in MEP. Major CNS fatigue! All other measures of central fatigue, namely ICF, LICI and SICI, were unaffected, so only certain aspects of CNS functioning seem to be susceptible to fatigue.

In contrast to the conventional wisdom that CNS fatigue takes longer to recover from than peripheral fatigue, it only took 20 minutes for the CNS to recover.

Other research confirms that CNS fatigue is short-lived and CNS fatigue recovers much quicker than peripheral fatigue: some recovery of voluntary activation occurs within 10 seconds. This probably explains the lack of CNS fatigue in the elite athletes: Howatson et al. measured CNS fatigue 10 minutes post-workout. Any CNS fatigue could have already dissipated in that time.

The major CNS fatigue after biceps curls is noteworthy, since broscience tells us CNS fatigue mainly occurs during compound exercises involving more muscle mass. Other isolation exercises have also been found to cause CNS fatigue if they're performed eccentrically. Purely eccentric exercise, which requires special machines to only load the muscle when it is stretching and not when shortening, results in significant CNS fatigue that can persist for 48 hours, at least in untrained individuals. Much of the local CNS fatigue is caused by muscle damage.

Since deadlifts involve the largest amount of muscle mass of all common strength exercises, deadlifts are commonly said to induce the greatest amount of CNS fatigue. This too appears to be a myth. Barnes et al. (2019) found that a given heavy-duty powerlifting workout of squats resulted in the same amount of central nervous system fatigue as that workout of deadlifts. The same workouts of the different exercises both resulted in 5% to 10% reductions in central neural output, despite deadlifts involving more muscle mass. Squats in fact caused a greater reduction in MVIC force production, suggesting greater total neuromuscular fatigue. Another study by Belcher et al. (2019) confirmed that deadlifts induce similar total neuromuscular fatigue as squats and bench presses and take just as long to recover from. There was in fact again a trend for less fatigue after deadlifts.

Other research also finds little effect of the amount of used muscle mass on central fatigue during strength training, in contrast to endurance training.

- Bilateral leg extensions cause similar decreases in voluntary quadriceps activation as unilateral leg extensions, indicating that if there was any central fatigue in the first place, it was equal in both conditions.
- Leg extensions and leg presses don't significantly differ in how much neuromuscular fatigue they stimulate or their time-course of recovery after a hard workout. (Don't be fooled by the authors' conclusion: look at the actual data.)

The research thus doesn't support the idea that the CNS fatigues directly in proportion to the amount of muscle mass trained, at least not to any practical degree during strength training.

You may wonder: why do squats and deadlifts tire you out so much then if there's so little and short-lived CNS fatigue? They're just brutal exercises. The fatigue is psychological, not physiological. Humans are fundamentally effort averse. Evolution didn't shape us to enjoy putting heavy iron on our back, sinking down to the limits of our flexibility and tearing down our muscles. That 'fatigue' you feel indeed isn't just localized muscle fatigue. But it's also not CNS fatigue. It's your waning motivation, your mind whispering: "no more hard work now, time for comfort food and fun". It's weakness talking. To get strong, you'll have to push past your comfort zone.

In conclusion, the vast majority of fatigue you accumulate during a strength training workout is of local origin. Any central fatigue of neural origin, if it occurs at all, seems to be entirely acute, so it is not normally a concern for long-term recovery. Most of the fatigue you *feel* during your workouts is psychological fatigue. It's your waning motivation and the body's aversion to hard work. Unlike physical fatigue, you can safely ignore mental fatigue and push through it to the best of your abilities.

Understanding the nature of fatigue helps us determine what to do when we stop progressing in our programs.

What to do when progress stalls

At some point you will get stuck on a certain weight x reps even with the fanciest program. You add weight, your reps go down. You try to increase the reps, but you can’t. You deload, but then you get stuck at a similar weight x reps strength level. A single plateau can happen for many reasons, but a double plateau at the same strength level is cause to change the program.

> “The definition of insanity is doing the same thing over and over again, but expecting different results.”

The first thing you should do when you observe a plateau is determine if the cause is likely systemic or local.

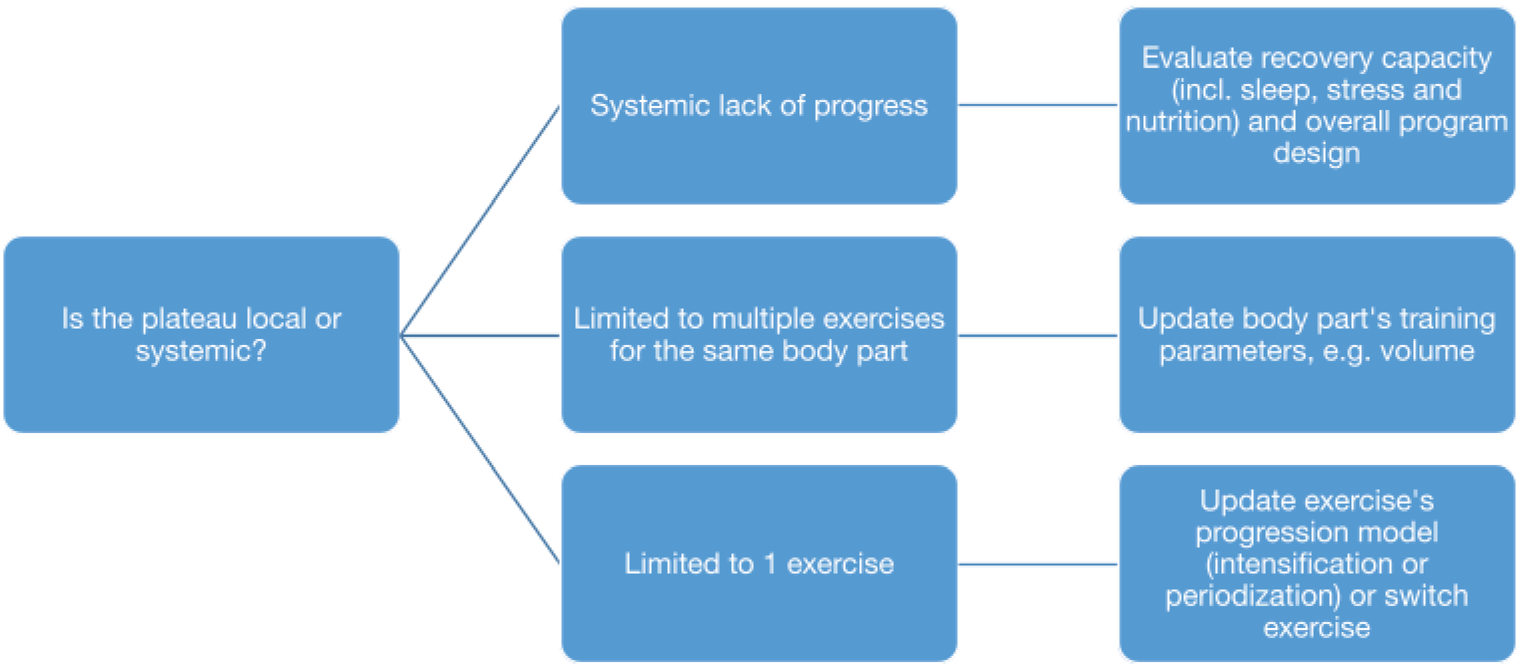
- If many exercises for unrelated muscle groups are stalling, the cause is likely primarily systemic. You should evaluate if all nutritional and lifestyle factors are optimized. Are they sleeping enough? Is energy balance appropriately set? Etc.
- If one or several exercises for the same muscle group are stalling, the cause is likely primarily local. The training program is not stimulating this particular muscle group well or the progression model for this particular exercise is not appropriate.

If the plateau is local, you should consider the possibility of undertraining, especially if you were progressing well earlier. The muscle group in question may have become too advanced for the given program. So you should reevaluate the muscle’s training status and progression since the start of the program. If multiple exercises for a muscle group are stalling, you can try increasing the number of sets in the program for that muscle and/or its training frequency. Increasing the training frequency is safer and typically results in a slight increase in repetition volume, so that's generally preferable to start with if conveniently possible in the program. If this is not enough to spur further progression, you should increase the total set volume for the muscle group in question.

If it is only a single exercise that's stalling and no other exercises involving the same muscle group, you probably only need to change that specific exercise's training program. You should evaluate if there's actually no progression or if you're not able to measure the progression. If you've been doing an exercise for a long time (months or years) and it's not a crucial exercise, such as the powerlifts for a Powerlifter, a stall in that exercise may only mean you can no longer progress a full rep or weight increment from session to session anymore, not that you're actually not progressing at all anymore. If this is likely the case, check the suitability of the rep target of the exercise. If the rep target is high compared to the average repetition count corresponding to the muscle's ideal training intensity, intensification is the simplest first step to take: decrease the rep target by at least 4 reps. A higher training intensity will typically increase strength development and make continued progressive overload easier. Make sure to maintain enough overall training volume. For maximum muscle growth, you generally do not want the reps per set to fall below 4, otherwise the repetition training volume may be insufficient for maximum muscle growth (see the course module on training intensity).

If you cannot intensify the rep target, and the exercise is easily replaceable, replacing the exercise is generally the most convenient way to re-enable you to monitor progressive overload. For example, if you're stuck on lateral raises because you cannot make the 2.5 kg jump to the jump to the next weight increment, it may simply be that the increment is impractically large. Switching to a different lateral raise variant is then a quick-fix.

If you want to stick with the exercise or none of the above strategies suffice, it's time for periodization.



A decision tree for what to do when progress stalls.

Periodization

Periodization is an often misunderstood topic in fitness. This is in part because many coaches intentionally overcomplicate it. Periodization is a cool buzzword, and drawing up fancy tables with lots of complex terminology can make you look smart. Plus, if you can make people believe you can plan their progress months in advance, they think you must really be in control of things.

Periodization is simply the organization of your training program over time. If your program is the same every week in terms of its parameters (volume, intensity, etc.), you have no periodization. If someone's just messing around in the gym, that would technically constitute ‘random periodization’.

When discussing periodization, it’s helpful to think in terms of cycles of your program instead of calendar days across the week with e.g. ‘Monday is chest day’. Definitions vary, but the following definitions are logical and convenient to use.

- A microcycle is one workout: a single training session.
- A mesocycle is equal to the number of days it takes you to complete all microcycles in it. So a program with 4 training days consisting of 2 different sessions, A and B, will have 2 mesocycles each week. The first week’s sessions are then 1A, 1B, 2A and 2B in that order. A mesocycle in this case lasts on average 3.5 days.
  Note that some people instead use the term mesocycle to refer to an entire training phase in a program.
- A macrocycle is the total length of a program. This is mostly relevant for athletes with an in-season and an off-season or strength athletes with competition dates throughout the season. Recreational trainees don’t have

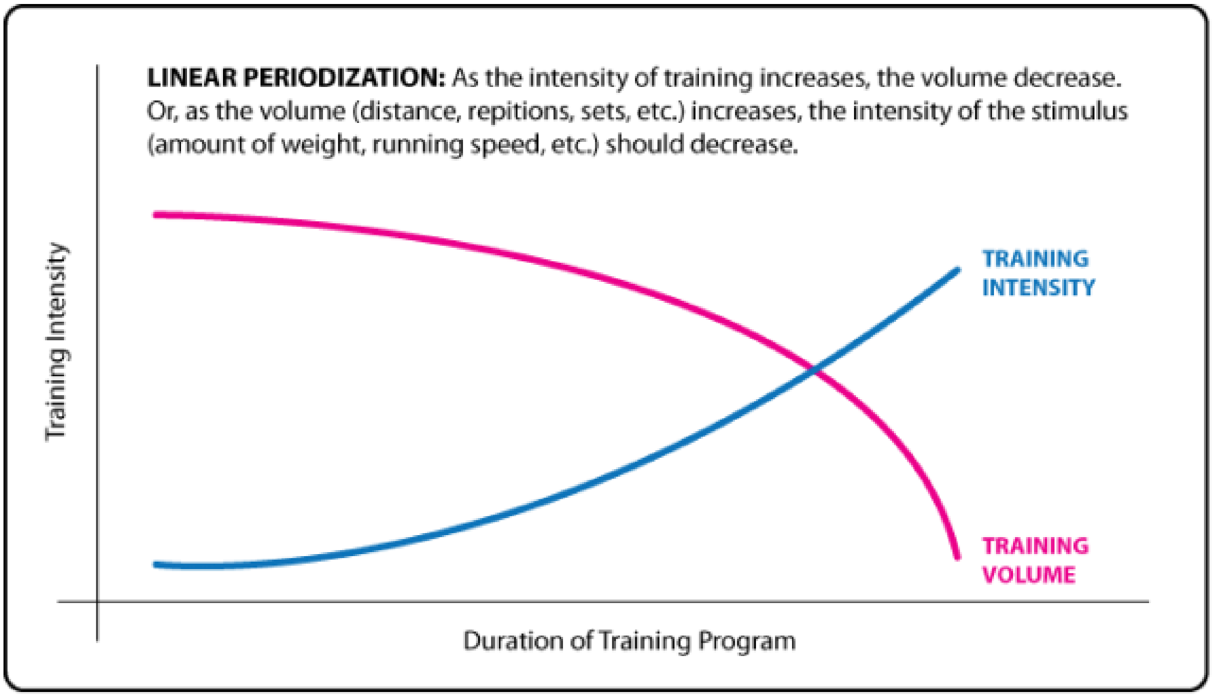
this, hence the term ‘program hopping’ for when regular gym folks try to copy this practice without results.

Periodization terminology is helpful, because it allows you to think in terms of time in a relevant way for strength training programming. Just like with nutrition, you should not restrict your thinking to calendar days. If you planned session A for Monday but you can’t train that day, do it on Tuesday and move up the entire program. It makes no sense to skip a microcycle in the program just because you couldn’t perform it on the same calendar day as last week.

There are multiple types of periodization that you should be familiar with.

Linear periodization

Linear periodization refers to an increase in training intensity and correspondingly a decrease in training volume across mesocycles of a program. In other words, a program with Linear Periodization will go from using lighter weights performed for higher reps to heavier weights performed for fewer reps.



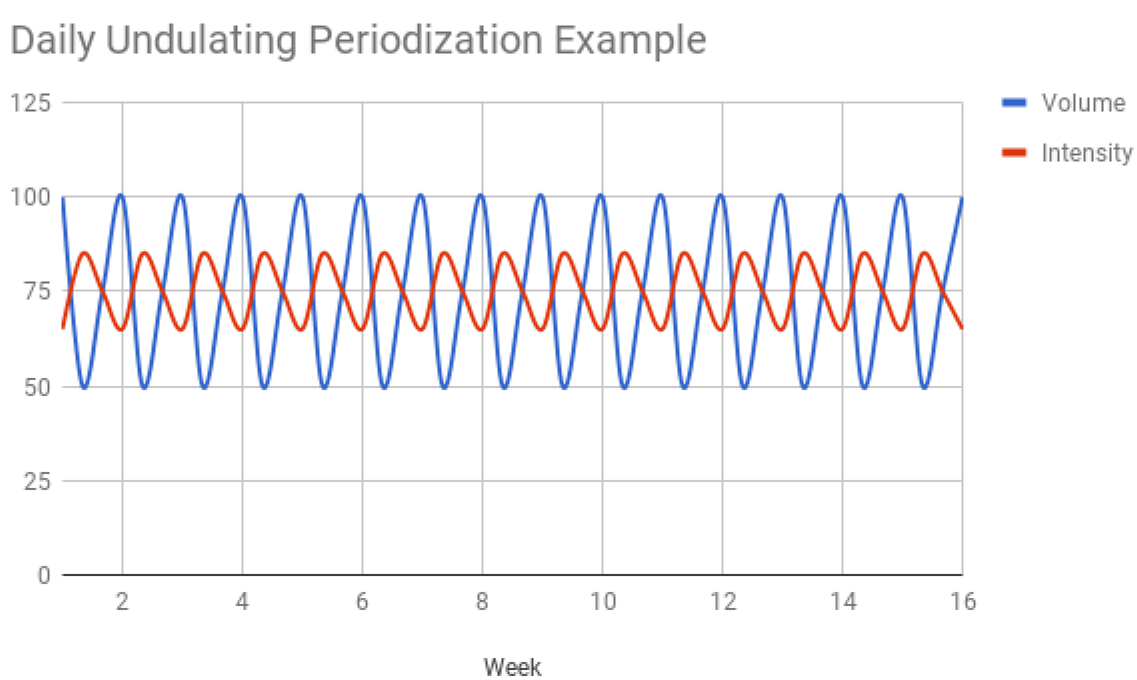
Linear periodization was designed for athletes. Its purpose is to peak in performance for a competition. Since bodybuilders have no need to peak in performance for their competitions and don't need to balance the development of strength, power and endurance at all but rather exclusively focus on muscle growth, bodybuilders have no use for Linear Periodization. While Linear Periodization can certainly be effective for muscle growth, it is no more effective than non-periodized programs with the same training volume [2].

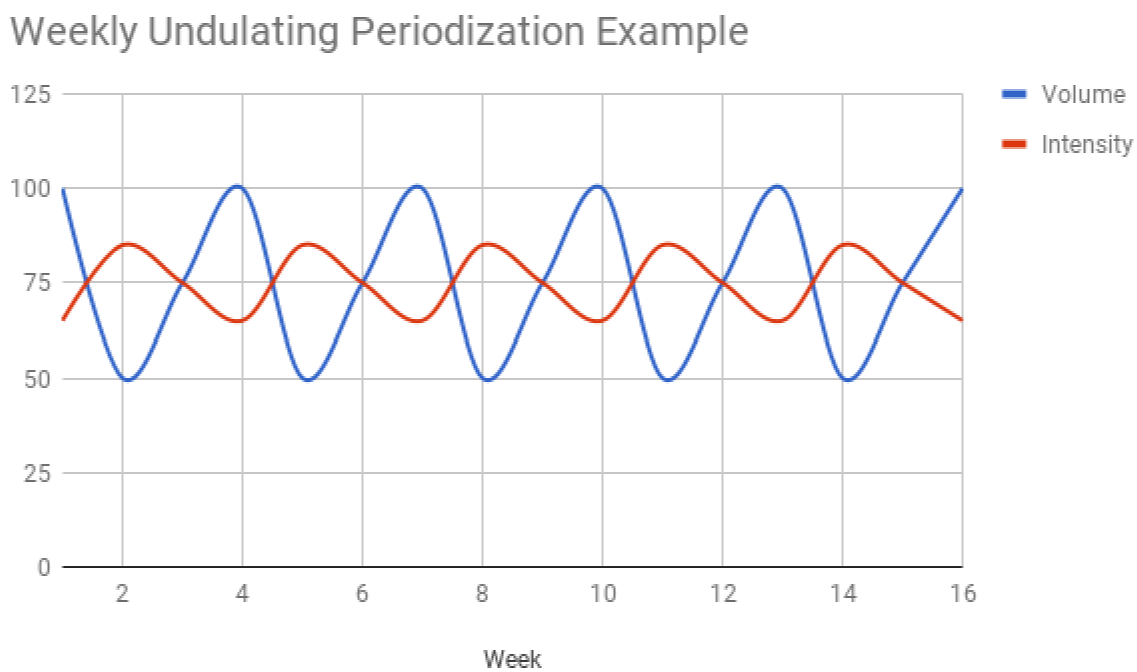
Linear Periodization does enhance strength development compared to no periodization according to a 2017 meta-analysis, but its effectiveness in this regard is confounded using higher training intensities closer to the final strength testing. Indeed, in other more practically relevant research, simple autoregulatory progressive overload beats Linear Periodization for strength development.

Plus, for strength development we have a superior periodization model: undulating periodization. Linear Periodization can also be combined with undulating periodization and this may be useful for Powerlifters and other athletes.

Undulating periodization / non-linear periodization

Undulating or so called non-linear periodization models have alternating or fluctuating training intensities over time. The intensity may fluctuate per week for Weekly Undulating Periodization (WUP) or per day for Daily Undulating Periodization (DUP). A traditional example of DUP is having 'strength', 'power' and 'hypertrophy' days each week, so every time you perform an exercise, you use a different rep range. WUP means you use the same rep range for the exercise throughout the entire week and then a different rep range the next week, before you go back to the first rep range again in week 3, etc.





Undulating periodization may allow you to induce different adaptation stimuli each workout. According to some research, [high and low rep training activate different growth pathways in highly trained powerlifters](), but [other research]() finds high and low rep training activate similar growth pathways even in trained subjects. Undulating periodization also allows you to incorporate high intensity work in your program without reducing its overall volume below the minimum required for maximum muscle growth. Your connective tissue, time allowance and motivation will often not allow you to get enough work in for optimal hypertrophy with 90+% of your 1RM. Since the purpose of undulating periodization is to alternate training stimuli, daily undulating periodization (DUP) makes more sense than weekly undulating periodization (WUP). WUP does not alternate training stimuli per session but per week, making it more like mini-block periodization in effect. In support of DUP over WUP, a 2022 study by Hernández-Davó & Sabido found that DUP resulted in more strength development than 2-weekly WUP.

Whatever the mechanism, which is still highly debated, experienced strength trainees gain more strength on the same program with daily undulating periodization than with either linear or reverse linear periodization or without any periodization [2, 3, 4, 5, 6, 7]. Undulating periodization is thus preferable over linear periodization.

In the short term that we have data on, on a volume-equated basis, undulating periodization is only useful to enhance strength development, not muscle growth [2]. Only two studies in the literature have found a trend for greater muscle growth with DUP compared to no periodization [2] and the trends were not statistically significant in either case. All other research has found no difference between undulating periodization and no periodization or Linear Periodization. The mechanism by which DUP increases strength is thus most likely not morphological in nature.

However, in practice if undulating periodization, specifically DUP, is successful at mitigating fatigue or improving strength, it may result in higher training volumes over time. Since increased training volume may enhance muscle growth, daily undulating periodization might improve muscle growth in practical settings when trainees are pushing their recovery capacity to the limit.

Undulating periodization is only useful for trainees beyond the novice level. Untrained and novice level strength trainees generally do just as well sticking to a consistent training intensity without undulating periodization [2]. Most research has not found any difference in the effectiveness of different periodization models in novice level lifters [2]. In novice lifters, the extra muscle damage induced by the variety of undulating periodization may even *hinder* progress. A beginner does not require any form of periodization, because a beginner on an optimized program should be able to continually increase the resistance without decreasing the training volume. It is simply mathematically implausible that any form of periodization can improve upon linear increases in weight. Most beginners training 3x per week can add 2.5 kg / 5 lb to the bar every session. If you only repeat each intensity once per week in this case with triple undulation, you'd have to add over 7.5 kg to the bar all at once very week to progress faster than 2.5 kg per session. That is very implausible.

In practice, implementing undulating periodization too soon may also reduce training efforts. By alternating between 2 rep targets instead of having only one, you effectively cut the minimum rate of measurable progression in half. As such, trainees that don't inherently push themselves 100% to their limits may be tempted to settle for a reduced rate of progression and, for example, progress only a single repetition per mesocycle when they could have progressed by that much twice per mesocycle without undulating periodization.

Undulating periodization, or periodization in general, is thus unlikely to be useful when linear weight increases are still possible. As linear progression in weight becomes impossible, however, undulating periodization may become useful. De Souza et al. (2018) found that while untrained individuals make the same progress over 12 weeks without periodization, with linear periodization or with daily undulating periodization, the time-course of their gains in muscle strength and size differed. The non-periodized group made the most gains in the first 6 weeks with a decline in progression afterwards, whereas the periodized groups continued to make gains at a similar rate as before. It is thus likely that over a longer period, as the trainees became more advanced, the periodized groups would start outperforming the non-periodized group. Since the rate of adaptation diminishes as you get more advanced, it now takes multiple bouts of adaptation to become sufficiently stronger to make the leap in resistance that your increment requires.

Even if undulating periodization doesn't benefit muscle growth, it is a very practical way to implement progressive overload, which allows you to measure if you're likely experiencing muscle growth.

Practical application

When an exercise can no longer progress linearly in weight or repetitions, you should implement undulating periodization. It will likely improve strength development and might slightly improve muscle growth as well.

Importantly, you should implement periodization on an exercise-specific basis. Many programs implement periodization for the whole program uniformly, but that does not make sense, because muscular adaptations are largely a local process and different exercises in a program will have different rates of progress and different increments. You should thus evaluate for each exercise independently if undulating periodization is likely to speed up progression.

When first implementing DUP, a useful rule of thumb is to set the 2 rep targets at least 4 reps or 10% of 1RM apart, e.g. 8 and 12 or 85% and 75% of 1RM, to prevent overlap in the weights used in both tracks and differentiate the stimuli at least somewhat. The minimum gap works well when your main reason to implement DUP is to be able to measure progressive overload. For example, when you stall on linear progression with a rep target of 7, you can switch to undulating progression with rep targets of 5 and 9. If you implemented the muscle-specific hypertrophy method and found non-standard results, like 11 reps at 80% of 1RM, it's better to reset the rep targets by using new percentages of 1RM. For example, if you stalled on linear progression at 80% of 1RM, you can switch to 85% / 75% of 1RM undulating progression.

To truly differentiate the training stimuli, however, you likely need a bigger gap in rep targets. In advanced trainees for exercises that lend themselves well to be performed with low as well as high rep targets, you can extend the gap all the way to the minimum and maximum viable rep targets, such as 85% / 30% of 1RM for leg extensions or 90% / 60% of 1RM for leg presses.

Since a good program for an advanced trainee typically has multiple exercises for every muscle group, you can decide whether you want a small or big spread in rep targets for an exercise based on your other rep targets for that muscle group. For example, if your leg press stalls and you already do high rep leg extensions, there's probably no need to go with a super high rep target for leg presses as well and you'll make better strength progress at higher intensities. Conversely, if you have no high rep work in your program anymore because you intensified all your rep targets over time, it's good to introduce a high rep target.

At some point, a trainee may stall even on an undulating progression model with 2 different rep targets. Triple undulation could be implemented then to alternate between 3 different rep targets. However, unless the trainee has achieved an elite strength level for this exercise by this time, the need for triple undulation often suggests something is amiss with the program or you are better off replacing the exercise. Powerlifters and Olympic Weightlifters may thus require triple undulation, but recreational trainees have more leeway in this regard and can replace stagnant exercises when highly complex periodization would become necessary to induce further progress.

In fact, replacing the exercise at this point may be preferable for muscle growth due to the diminishing returns you're likely to get from progressing even further on a given exercise. A new exercise may allow you to stimulate muscle growth in different fibers that still have more capacity for growth. When triple undulation is necessary for any progression, is it likely that any further strength development will be mostly neurological in nature.

Muscle confusion

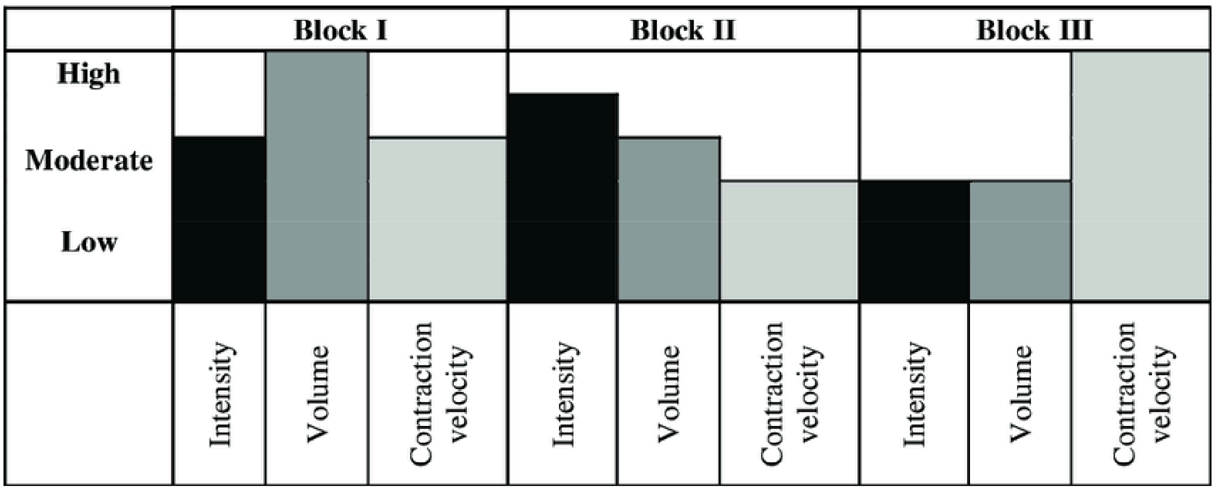
Many bodybuilders constantly switch up their training programs to the point they're doing a different workout for each muscle every time they train it. The rationale for this is called 'muscle confusion' with the idea being that by confusing the muscle, you prevent it from adapting to the training program. This idea is completely misguided. First, you can't confuse contractile tissue, m'kay? Second, adaptation is not undesirable. On the contrary, **adaptation is the very goal of a training program**: by applying stress on a muscle in the form of mechanical tension, we cause it to adapt to that stress and protect itself from it by making itself bigger and stronger. Muscle doesn't seem to have a 'history function', as changes in training volume are only weakly to moderately correlated with muscle growth. Any correlation is probably caused by the training volume itself rather than the change therein, meaning the tissue in a given state responds to a given stress the same way each time and there's no need to mix up the training stimulus just for the sake of it.

Damas et al. (2019) showed that 'muscle confusion' doesn't work. A group of strength-trained men trained one leg with 4 sets of 9-12 reps to failure for each exercise with progressive overload. The other leg implemented 'muscle confusion' by rotating through 4 different workouts: either the same workout as the control group, an eccentric-only version, a higher-volume version with 6 sets or a higher-rep version. Despite training with a significantly higher volume on average, the 'confused' leg didn't gain more muscle. These findings were replicated by Angleri et al. (2022).

Baz-Valle et al. (2019) also found that there’s no need to ‘confuse’ your muscles with a ‘novel stimulus’ every workout. In otherwise identical, work-equated programs in trained men, randomly generating exercises for each workout produced non-significantly worse muscle growth and strength development than sticking with a fixed exercise selection. (See the exercise selection module for more details on this study.)

Block periodization

A more sensible and structured way to implement variety in training stimulus is block periodization. Block periodization is way to structure training programs in which training programs are separate into different phases ('blocks') with different emphasis.



An example of block periodization that could be characterized as hypertrophy-strength-power cycle. Source

Block periodization makes sense for athletes with different in-season and off-season training requirements, especially concurrent athletes that must balance endurance, power and strength adaptations. For recreational trainees, however, the theory of block periodization has little theoretical basis. The goal of training for most people doesn't change over time (get stronger and/or bigger) and someone's physiology also doesn't change appreciably over the course of a few weeks, so why would the ideal training stimulus fluctuate over time?

As expected based on the lack of sound theory, empirical research generally finds no advantage of block periodization compared to no periodization or undulating periodization for muscle growth and strength development. Taken as a whole, the data favor undulating periodization over block periodization for muscle growth.

- In untrained, elderly individuals, there seems to be no advantage of block periodization over undulating or even no periodization for strength development or body recomposition.
- Bezerra et al. (2018), again studying untrained, elderly individuals, found a trend for greater muscle growth and strength development in a training program where strength, hypertrophy and power work were all completed in the same session compared to the same training split over blocks of hypertrophy, strength and power work.
- A study in Division I track and field athletes by Painter et al. (2012) found no significant differences between block and daily undulating periodization in strength development. However, the undulating group accomplished higher training volumes in the later phases of the study when the block periodization group was in its strength and power phases, which may have biased the results in favor of the undulating group. There were also slight trends for better measures of explosiveness in the group with block periodization.
- Bartolomei et al. (2014) compared a block periodization program to linear periodization in seriously strength-trained male athletes. Both programs had the same total work volume across the study, but the block periodization group split this into an accumulation/hypertrophy phase, a strength phase and a power phase. At the end of the study, there were no significant differences in changes in body composition, strength or power, although there was a trend for greater 1RM bench press strength development in the block periodization group. The block periodization group performed most of its strength work closer to the final testing point, thus biasing the results in favor of the block periodization group. This is unfortunately a common limitation of periodization research with testing only at the start and very end of the study.

- Bartolomei et al. (2015) compared an equal total work volume with block periodization program to weekly undulating periodization (WUP) in strength-trained women. The WUD group experienced a significantly and considerably greater increase in their 1RM squat and thigh cross-sectional area. Other measures of power, strength and body composition didn't differ significantly between groups.
- Gavanda et al. (2019) compared an equal total work volume with block periodization to daily undulating periodization (DUP) in strength-trained adolescent American football players. There were no significant differences between groups in strength (incl. 1RM squat and bench press) or body composition measures. However, there was a trend for the DUP group to lose more fat in effect size analysis and this became significant in post hoc analyses. Effect size analysis also suggested greater total body gains in fat-free mass and muscle mass in the DUP group.
- The only study favoring block periodization over no periodization is Carvalho et al. (2020). In this study, muscle growth was greater in a group performing a 3-week strength phase followed by a 5-week bodybuilding phase than a group performing an 8-week bodybuilding phase. However, a similar study by Camargo et al. (2021) found that it didn't matter in which order 2 groups performed their strength or hypertrophy/strength-endurance cycles, indicating the former study's benefits likely were likely due to combining high and low intensity training, not in specific the order of which. Based on the aforementioned literature, it's likely better to include high intensity training regularly without dedicating a specific phase to it (e.g. with DUP). Then you won't compromise muscle growth during the strength phase, which happened in this study, but you'll still optimize strength gains, which may benefit long-term muscle growth.

- A 2022 study by Hernández-Davó & Sabido found that DUP resulted in more strength development than 2-weekly block periodization/WUP. All groups consisted of trainees that could squat 150% of bodyweight and they performed the same total training volume tonnage during the program. The only variable in the programs was when they squatted with each training intensity: 30% ('power'), 75% ('hypertrophy') or 85% ('strength') of 1RM.
- Barolomei et al. (2023) found greater overall strength and size gains from a 10-week mixed-session periodization program than an identical program with block periodization (4 weeks ‘hypertrophy’, 3 weeks strength, 2 weeks power). The mixed-session group performed all 3 types of exercise each workout (at a lower volume to equate total program volume) as opposed to in separate blocks. The subjects were seriously strength-trained men, including powerlifters.

Below is a literature overview on periodization for those interested in the specific studies. Since research and theory generally agree that fancy periodization models are unnecessary for untrained individuals, this overview only contains volume-equated studies in strength-trained individuals.

➢ Research overview

Effect of periodization on strength and body composition changes in trained subjects

Functional overreaching

A traditional model of block periodization relies on the concept of functional overreaching to improve progress. The idea of functional overreaching is to induce strategic overreaching with an accumulation phase, followed by a deload phase, in which supercompensation occurs so that you keep growing during the deload. Thus, in contrast to a regular stress-recovery-adaptation cycle, you dig yourself into a deeper recovery hole across multiple workouts (weeks) and afterwards the idea is you get a massive supercompensation phase. It's an interesting theory, but does it work in practice?

Coutts et al. (2007) studied competitive rugby players performing a 6-week overreaching program with progressively increasing training volume. During the program, strength in the squat, bench press and chin-ups decreased significantly. After the accumulation phase, they performed a 1-week taper with a low volume of submaximal exercise. This resulted in significant strength increases in the above 3 lifts, but the taper only brought strength back to baseline, not above it. Bodyweight remained exactly the same from pre- to post-taper, suggesting no muscle growth occurred. Thus, the taper was highly effective to allow recovery to finally occur, but no more supercompensation occurred than you'd expect from a regular workout. In other words, these trainees spent 7 weeks making practically no gains(!) See the study data below for those interested in more details.

Table **6** Performance and physiological variables during 6 weeks of overload training and 7-day taper (mean ± SD)

Measure	*Pretraining*	*Post-training*	*Taper*
Body mass (kg)	86.1 ± 10.0	85.3 ± 9.4	85.3 ± 9.6
MSFT (m)	2291 ± 127	2054 ± 199^{*M}	2437 ± 67$^{\#M}$
Vertical jump (cm)	61.7 ± 10.6	59.4 ± 9.6^{M}	62.4 ± 9.9^{M}
Running speed			
10 m (s)	1.89 ± 0.09	1.92 ± 0.11	1.88 ± 0.10^{M}
40 m (s)	5.42 ± 0.18	5.46 ± 0.20	5.44 ± 0.19
Isoinertial strength			
3-RM squat (kg)	141.2 ± 21.8	133.9 ± 18.2^{M}	143.6 ± 24.8^{M}
3-RM bench press (kg)	115.0 ± 18.7	109.3 ± 17.9^{M}	115 ± 17.3^{M}
Chin-up$_{max}$ (reps)	15.6 ± 1.9	13.4 ± 2.1^{M}	16.0 ± 1.7^{M}
Isokinetic strength and power			
1.05 rad · s^{-1}			
Peak quadriceps torque (Nm)	222.4 ± 50.6	164.5 ± 19.5*	239.5 ± 38.2$^{\#}$
Peak hamstrings torque (Nm)	151.8 ± 44.9	117.3 ± 20.4*	135.6 ± 16.2$^{\#}$
Set work (J)	967 ± 244	724 ± 116*	1074 ± 152$^{\#*}$
5.25 rad · s^{-1}			
Peak quadriceps torque (Nm)	149.1 ± 20.9	162.8 ± 15.0	176.2 ± 28.7
Peak hamstrings torque (Nm)	96.5 ± 11.8	108.4 ± 13.6	128.1 ± 22.3*
Set work (J)	603 ± 83	705 ± 91	770 ± 103*

$^{\#}$ Significantly different to previous measure ($p < 0.05$); * significantly different to pretraining ($p < 0.05$); ^{M} minimally clinically important difference compared to previous measure

Up until 2019, no study had ever documented prolonged supercompensation in muscle mass after overreaching. Bjornsen et al. (2019) were the first to show strong evidence of positive functional overreaching. In this study, strength and muscle fiber size kept increasing for 10-20 days after a short overreaching phase with blood flow restricted exercise performed 1-2x per day for 4 sets to volitional failure. Thus, functional overreaching *can* in some contexts induce prolonged muscle adaptations. The next question is: are the total gains over the overreaching and deload period together greater than the gains you could achieve with constant training?

The answer in this study appeared to be no. The total daily muscle growth rate in this study was lower than in previous studies with a similar design where muscle growth occurred more linearly. Essentially, overreaching *delayed* muscle growth rather than potentiating it. During the overreaching phase, strength as well as muscle size slightly decreased, even though the participants were not even strength-trained to begin with. The overreaching phase corresponded with major elevations in markers of muscle damage, notably creatine kinase, in several participants. This supports previous research that excessive muscle damage delays muscle growth. Muscle damage forces your muscles to spend a lot of time repairing damaged proteins instead of building new ones.

Also, the cross-sectional area of the rectus femoris and muscle thickness of the vastus lateralis did not show a delay in growth. Their size increased quite linearly during training and decreased during detraining. This may be confounded by edema from muscle damage, but it doesn't support functional overreaching.

Vann et al. (2021) studied trained men undergoing a 6-week accumulation phase with a training volume up to 32 sets per exercise per week, followed by a deload week with either very light training (‘active recovery’) or no training at all. Neither protocol resulted in any muscle growth during the deload week. Non-significantly, both groups actually lost a little bit of muscle and gained a little bit of fat. There was also no improvement in mood states. As such, in this study the deload weeks were largely a waste of time.

In conclusion, functional overreaching can in some contexts induce delayed gains in strength and size in a subsequent deloading period, but these gains don't necessarily improve fitness above baseline and there is no evidence functional overreaching can improve the net rate of progress compared to a similar period of constant training. As such, functional overreaching represents a high-risk, low-reward programming strategy that should not be used by recreational trainees under normal training circumstances. At best, functional overreaching can be useful before holidays or traveling when you can't or don't want to train. You can achieve this by increasing training volume substantially in the last week before the time off. If safely possible, a logical way to approach such a scenario is to put the training volume from the time off into the week before the time off. So if you take a week off, you double your training volume the week before to overreach and use your time off to hopefully grow despite minimal exercise. However, it's common to see significant fat gain in these scenarios, so it's much safer and reliable to simply keep training during the holiday.

Deloading

Sometimes, AVT is not enough to prevent overreaching from occurring. This is when deloads are applicable. A deload is a reduction in weight to reduce the training stress. Sometimes the word deload is also used to refer to a more general reduction in training stress, like a reduction in training volume by reducing the number of training sets. Even more generally: "Deloading is a period of reduced training stress designed to mitigate physiological and psychological fatigue, promote recovery, and enhance preparedness for subsequent training."

Traditional deloading

A traditional implementation of deloading is to take 1 week off training or do greatly reduced training after each 1 month of your program. These numbers are a completely arbitrary artifact of the Gregorian calendar. The passing of a lunar cycle does not fatigue your muscles, m'kay? Even if you use any other schedule, at best, it's an educated guess about when overreaching is likely to occur. You can't always predict in advance when an individual will experience higher stress in their life, sleep less well or deviate from their diet. Overreaching in any program can occur at many different time points for different people.

Taking exactly 1 calendar week off training is again arbitrary Gregorian calendar bias. As you learned, your muscles generally recover from any practical workout within 72 hours if you're no longer a beginner and you're accustomed to the exercises [2, 3, 4]. Any practically viable training protocol should not require more than 5 days of rest afterwards to recover from it. (See the training frequency module for more studies.)

The third arbitrary aspect of the traditional deload week is that you deload the entire body. As you learned, neuromuscular fatigue is largely a local process, as is connective tissue injury. Fatigue in your biceps does not affect your squat. It makes no sense to stop squatting because your biceps hasn't recovered. Deloading should thus ideally be exercise- or body part-specific.

A significant downside of taking a week off training is that it can easily result in fat gain and a disruption of fitness habits.

Another downside is that taking a week off reduces your rate of recovery. Being sedentary significantly slows down how fast your tissues heal, as it limits blood flow, immune system activity and our overall metabolism. Our bodies heal faster when we keep exercising [2, 3, 4].

A study by Coleman et al. (2023) found that the traditional approach to deloading – taking a week off after each 4 weeks of training – is likely more harmful than beneficial. The researchers compared 2 groups of strength-trained men performing an intensive 9-week program. For the measured muscles, the calves and the quads, the men were instructed to do 20 sets per week to failure with verbal encouragement. One group did a deload week without any training in the middle. The other went full-steam ahead the whole 9 weeks. The 'deloads are for wimps' group achieved greater gains in 1RM and isometric strength (85-92% Bayesian probability of being superior). Muscle growth was similar between groups without any clear differences. In absolute terms though, 8 out of 10 effect size measures of muscle growth favored not deloading.

The arbitrary timing and unnecessary whole-body nature of traditional deload weeks can be improved upon by autoregulating our deloads and performing them reactively rather than proactively.

Reactive deloading

Reactive deloading can solve the problem of the interindividual variability in the necessity of deloads. As the name suggests, a reactive deload is not scheduled ahead of time. Just like AVT, reactive deloading is only applied to the affected exercise(s) in a single training session.

Specifically, a reactive deload is implemented whenever a trainee does not progress as planned for that exercise and it is deemed likely that this was due to overreaching, not a lifestyle factor like lack of sleep or a nutritional factor like undereating. A decent rule of thumb is that reactive deloads are warranted when someone does not progress 2.5% in strength on an exercise or if someone's reps end up lower instead of higher than last time on an exercise. Advanced trainees may need to use 1% progress as their criterion, as they can't expect to gain 2.5% strength consistently anymore.

There are 2 other considerations for whether you want to implement reactive deloads.

1. Terminal consistency: Exercises that score poorly on this principle have an inherently higher variability in performance. As such, there is a decreased probability that lack of progress is due to overreaching. Therefore, reactive deloads may result in undertraining and are not advisable.
2. Recovery capacity variability: The more variable someone's rate of recovery, the greater the potential need for reactive deloading. If someone has a very irregular recovery capacity due to, for example, a variable sleep pattern, poor diet adherence or due to concurrent sport-specific training, there is a greater need for reactive deloading to address the likely underrecovery.

Based on the above factors, bilateral deadlift exercises usually benefit from reactive deloading, since they have excellent microloadability and terminal consistency. An example of an exercise that rarely requires a reactive deload is the delt lateral raise, because it is generally impossible to micro-load it well and small changes in body posture or arm positioning can affect performance significantly.

When you've established that reactive deloading is useful for an exercise in your program and a plateau occurs in any workout, you implement a reactive deload as follows. You replace your remaining sets with low rep, explosive technique work: 1 to 5 reps per set at 60-70% of 1RM (roughly equal to a weight you could do 12-20 reps with). This type of speed work allows you to reach high muscle activation levels and work on your technique while only inducing minimal neuromuscular fatigue. It's important to realize that to reap these benefits without the cost of high further fatigue, it has to stay speed work. If your movement velocity decreases noticeably at all during any set, you are going far too heavy and only digging yourself deeper into your recovery hole.

In the presence of more severe fatigue, it is better to deload reactively by 100%, i.e. by skipping all subsequent sets altogether. Speed work is appropriate if you only just missed the last rep needed to progress as planned or you feel like you could have hit your planned number of reps if your technique was a bit better. When you didn't come close to your planned performance, when your trained muscles were still extremely sore or when you experienced pain, speed work may still be too much and you're better off just moving on to the next exercise.

Let's look at some examples. Say an advanced bodybuilder has planned to perform 350 pounds for 5 reps in the squat this workout, which would be a new best in the program. He's already implementing AVT and undulating periodization with a training volume of 4 sets and progress is generally consistent, so reactive deloading is implemented for the squat. First work set, he manages only 4 instead of 5 reps. Since he likely hadn't recovered sufficiently yet, he reactively deloads to prevent overreaching: for his remaining sets he drops the weight to 250 pounds and performs 3 more sets of 3 as speed work.

Example 2: Say that same bodybuilder does lateral raises later in the same training session. Here too he doesn't progress as planned, reaching 11 reps with 35 lb again just like last workout, but since lateral raises have an inherently much higher variance in their performance, he doesn't implement a reactive deload and performs his remaining sets as planned (with AVT).

In sum, reactive deloading allows you to program deloads in your program in a systematic but individualized manner so that you reduce your training stress only when needed. These reloads are also specific to the muscle groups that actually need it, in contrast to proactively and arbitrarily scheduling a whole-body deload in your program when you guesstimate it may be needed.

Overtraining

Overtraining is another topic in the strength training community riddled with broscience and imprecise definitions. Overtraining is often said to be caused by central fatigue, but as you learned, central fatigue is rarely a limiting factor of your recovery. So does overtraining actually exist?

Yes, overtraining syndrome is a real phenomenon. However, there is no universally accepted definition of overtraining yet and we don't know how exactly it occurs. Even the hormonal effects of what is supposedly overtraining syndrome vary enormously from study to study: on average 'overtrained people' tend to have normal resting hormone levels. The only consistent marker of overtraining is a decrease in performance. What we do know is that overtraining is exceedingly rare and generally not just the result of training but rather high psychological stress, like that of competing.

Importantly, in science, true overtraining syndrome is usually a term reserved for a period of weeks or months of severe psychological problems, utter lack of motivation to train and significantly impaired performance. It's not just 'feeling a bit tired'. More short-term decreases in performance are sometimes called overreaching, though it's unclear if overtraining is simply a more advanced form of overreaching.

Due to the lack of a specific operational definition of overtraining, many people are inclined to think along the lines of: "Oh hey, I'm not that motivated to train this week. I must be overtraining." This is generally a cop-out, because the most fundamental symptom and the single necessary and universally agreed upon condition for overtraining of any kind is reduced performance. Overtraining occurs when you chronically dip below the point of recovery in the GAS-cycle. So by definition, any strength gains during that period invariably exclude the diagnosis of overtraining. Let's reiterate that. **If you are gaining strength, you are not overtraining.**

The reverse diagnosis is also false: if you are losing or not gaining strength, you are not necessarily overreaching. You may actually be undertraining. Or your exercise technique needs work. Or your circadian rhythm is disrupted. Or your diet isn't good enough. Many things other than overtraining can explain lack of progression or detraining.

On the other hand, many people have great fluctuations in their performance over time and it has become bro-lore that 'you have good and bad days', suggesting there's a significant variability in your strength across days. However, randomness is simply variation that is not yet explained. All variance can be explained. In Menno's experience, large fluctuations in performance in a properly structured strength training program are generally caused by either circadian rhythm disturbances, such as training at variable times of day, inconsistent exercise technique or variable training effort. Day to day variance in performance in serious trainees on a structured program with good technique is minimal, a percent or two at most normally.

So when is someone at risk for overtraining? There are actually 2 kinds of overtraining.

1. Volume overtraining. And we're not talking about a few sets of squats a couple times a week here. We're talking about doubling your distance running volume to 109 miles (175 km) a week within a month, military training, cycling of 2-3 hours a day or high-intensity rowing for 3 hours a day. Overtraining is far more common with endurance exercise than strength exercise.
2. Intensity-volume overtraining. Though volume is rarely a concern during strength training in comparison to the above, very high intensities can increase the recovery demand. Again, we're talking extremes to reach overtraining, like performing 10 squat 1RM attempts every day for 2 weeks straight.

Note that in the case of intensity-volume overtraining, both the intensity and the volume need to be high. Advanced powerlifters can make excellent progress while training their 1RM every day followed by 5 sets of 3 reps at 80% of 1RM for over a month.

Overtraining also almost exclusively occurs in athletes in energy deficit. The risk of overtraining is thus likely substantially reduced when bulking.

To put the prevalence of overtraining in perspective, Menno has coached hundreds of trainees over the last decade and pushes many of them to their limits. He hasn't seen a single case of verified overtraining. The handful of suspected cases all turned out to have other causes, such as hypogonadism, hypothyroidism and fibromyalgia.

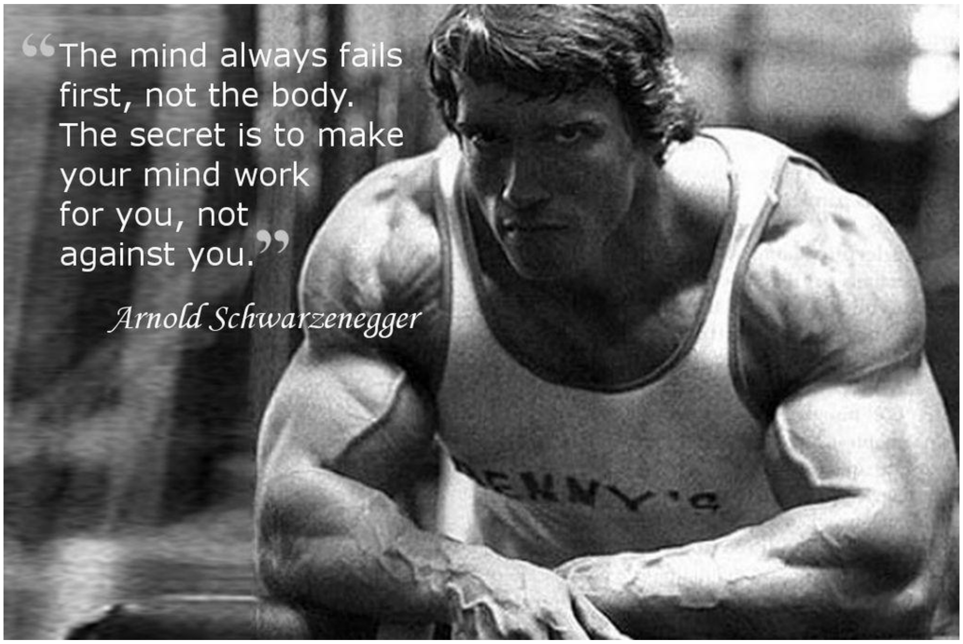
Menno has also experimented with extreme volume training in 2016. For ~2 months each, he trained with a daily set volume of 10, 8, 6 and 4. Doing 10 sets for each muscle every day resulted in loss of performance but no other signs of overtraining; 8 sets resulted in strength maintenance; 6 sets still allowed progression but no more than 4 sets. This supports that overtraining doesn't happen suddenly. It is a continuum that can be separated into the following phases.

1. Undertraining: not enough volume for strength progression.
2. Effective training: supercompensation takes place as planned, resulting in strength progression.
3. Excessive training: you only just recover from workout to workout, not gaining any net strength over time because there is not enough time for supercompensation.
4. Overreaching: you underrecover and lose strength from workout to workout.
5. Overtraining: long term overreaching may culminate in true overtraining syndrome.

In practice, the order of overtraining is generally more as follows.

1. Your mind will give out. For most people in the gym, it's not true that "the mind is strong, but the flesh is weak". That's a metaphor from the Bible based on the quote, "the spirit is willing, but the flesh is weak." It actually means that we find it difficult to resist temptation, to do what is right instead of what our feelings tempt us to do. And that's exactly what will happen when things get tough. You'll start looking for excuses, shortcuts and magic pills. Don't give in. Remember the lectures about mental vs. physical fatigue.

2. Your connective tissue degrades. Muscle is more plastic and can heal faster than your tendons and ligaments, so with heavy training, overuse injuries can occur in your joints before the actual muscle tissue starts limiting you.
3. You actually become overtrained. Almost nobody ever reaches this stage, as they are prevented by their injuries and fatigue from doing so.



Practical application

To put everything together, below is a guide with a set of concrete progression guidelines. They include autoregulated progression models, including reactive deloading, for straight sets and sets across, undulating periodization and cluster sets. You should in principle think of these as examples. Don't limit yourself to just these models. There are many more viable progression models. Successful progression models have 4 key features.

1. They provide a systematic method to achieve progressive overload.
2. They autoregulate the rate of progression.
3. They manage fatigue.
4. They have a benchmark of performance.

A benchmark is a strictly defined measure of progress. Examples:

- Your 8 RM.
- Your 3 RM at 2 reps to failure.
- Total reps performed over 4 sets with a fixed 3-minute rest interval.
- Estimated 1RM.

Here are some examples of failure due to not having a benchmark.

- Continuously increasing the weight while your reps per set keep decreasing and 3 weeks later you find out your 10 RM hasn't changed at all.
- Progressing in weight with 5x5 without monitoring the rest interval. A month later you spend an hour on those 5 sets, because you're no longer doing 5x5 with your 8RM but your 5RM, requiring full recovery before you can do another set.

- Progressing in the 10-rep squat without monitoring your inter-rep rest interval. Your 10 RM barely increases, because you're just resting longer and longer in between reps while you move up in intensity but not strength.
- As a powerlifter, training your deadlift for sets of 5 without resetting the weight each rep. Your deadlift bounce technique improves greatly, but you don't get much stronger getting dead weight off the floor (which should always be a powerlifter's benchmark for the deadlift).

➢ **Progression guidelines**