Optimal training program design fundamentals

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Contents

➢Lecture [optional]

Optimal program design: intensity, volume and frequency

In this module, you'll learn the fundamentals of optimal training program design. The most important variable of any training program is generally its training volume. Most other training variables matter primarily because they affect your training volume. For example, in this module we'll discuss training frequency, which is essentially the question of how we distribute our training volume across the week. But before we can meaningfully discuss training volume, we need to discuss training intensity. You'll understand why after the following sections.

After discussing training intensity, volume and frequency, we'll go into program customization methods, such as how to estimate how advanced a lifter is and how to handle underdeveloped body parts.

Training intensity

How many repetitions (reps) should you perform each set? This question can be reformulated as: what's the optimal training intensity? Training intensity in exercise science is defined as the percentage of your one repetition maximum (%1RM) with which you're training. A better terminology for training intensity would arguably have been relative load, as the word intensity is easily confused with *intensiveness*, which is a subjective measure of how effortful the training is.

Training intensity correlates with the rep count: see the table below for the conversion. For example, most people can do about 8 reps with 80% of their 1RM and 3 reps with 90%. By definition, anyone can perform only a single rep with 100% of their 1RM.

Estimated Reps at Percent of 1 Repetition Maximum

Reps:		1	2	3	4	5	6	7	8	9	10	11	12	15
%1RM	Brzycki	100	95	90	88	86	83	80	78	76	75	72	70	
	Baechle	100	95	93	90	87	85	83	80	77	75		67	65
	dos Remedios	100	92	90	87	85	82		75		70		65	60

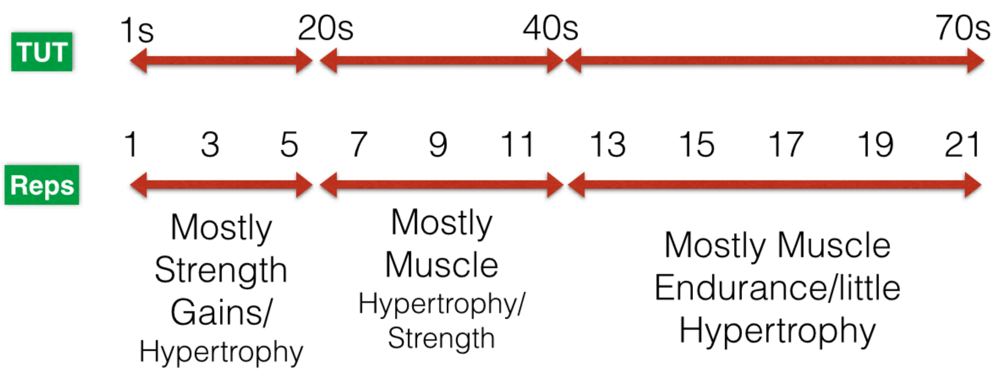
Brzycki, Matt (1998). A Practical Approach To Strength Training. McGraw-Hill.

Baechle TR, Earle RW, Wathen D (2000). Essentials of Strength Training and Conditioning, 2: 395-425.

dos Remedios R (2007) Men's Health Power Training, Rodale Inc. 23.

Table compiled by ExRx.net

One of the greatest broscience myths that persists to date is that there is an optimal hypertrophy zone of 6–12 repetitions (reps) which is best for muscle growth. This seemed to be based on nothing more than the subjective sensation of training, like most bro wisdom. When you perform sets with light enough weights that you can perform over 12 reps, you barely feel the first reps at all. It doesn't feel heavy enough. When you train with such heavy weights that you cannot perform at least 6 reps, you don't get a pump or burn. So the sweet spot from a sensory point of view seems to be about 6-12 reps per set.



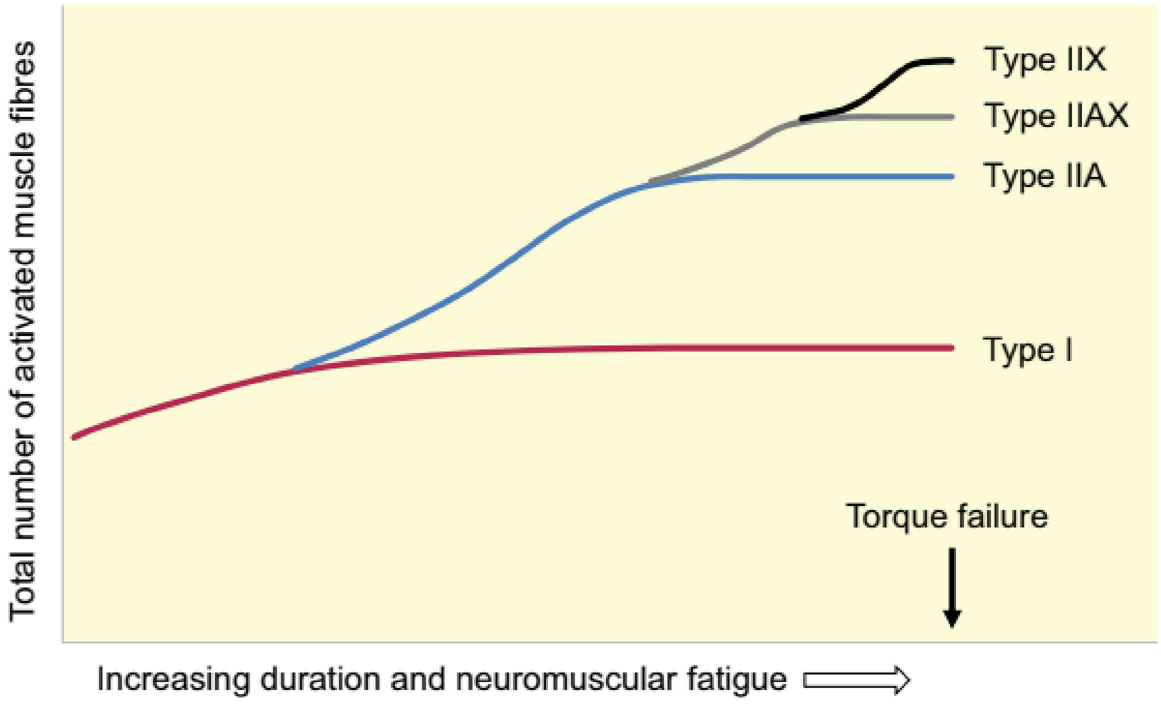
The hypertrophy zone: just because someone turned it into a fancy image doesn't make it true.

If you think about what makes muscles grow, however, it makes no sense that heavy weights would be inferior to lighter weights. The primary driver of muscle growth is mechanical tension, as you learned in the module on understanding muscle growth. All else equal, relative load linearly corresponds with force production requirement, which linearly corresponds with the amount of tension created by the muscle. So lifting heavier weights induces more mechanical tension in your muscles, which means they should be, rep for rep, more effective for muscle growth than lighter weights.

And indeed, not a single study has ever found that a given volume of low rep work results in less muscle growth than that volume in the form of higher rep work. All the way back in 2002, Campos et al. found that 4 sets of 3–5 reps resulted in just as much muscle growth in all muscle fibers as 3 sets of 9–11 reps. All research to date, including a 2021 meta-analysis, has consistently confirmed that a given number of repetitions of low-rep work results in similar levels of muscle hypertrophy as that volume in the form of higher reps per set while often providing better strength development to boot [2, 3, 4].

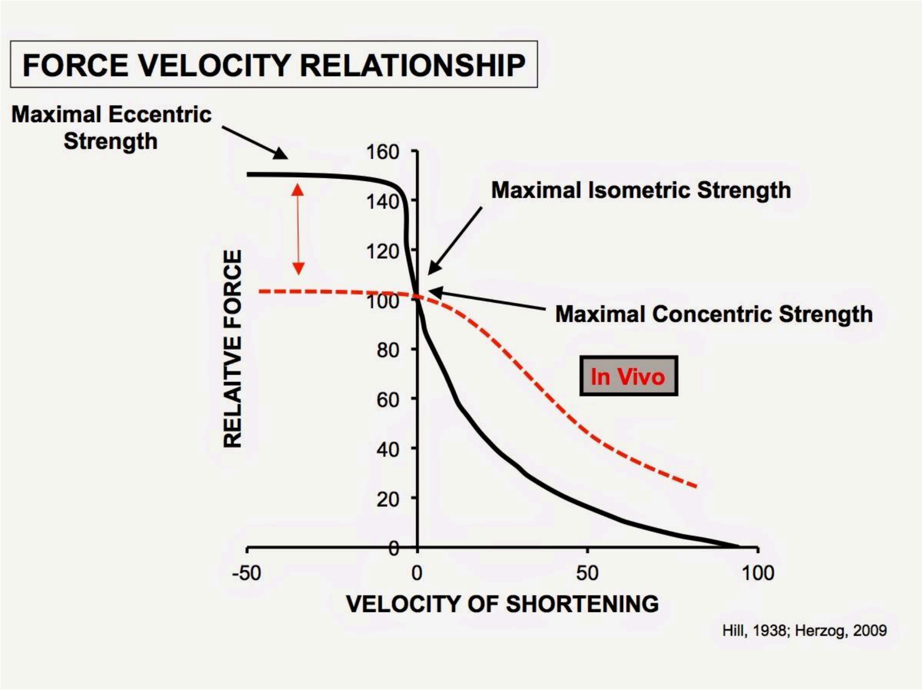
The broscience myth of the 6-12 rep hypertrophy range didn't die for many years, however. It finally started to crumble over the last few years when studies started repeatedly showing that even sets of very high reps, down to 30% of 1RM, are just as effective for muscle growth as sets in the traditional bodybuilding rep range (~80% 1RM) when taken close to failure [2, 3, 4]. Training close to failure seems to be crucial for high rep sets to be maximally effective. Simply lifting the simple total tonnage with 30% of 1RM as with 80% or 90% of 1RM weights doesn't stimulate as much muscle growth [2]. If you don't train with either a heavy weight or close to failure, you won't achieve full motor unit recruitment. If you'll recall from the module on understanding muscle growth, higher-threshold motor units are only recruited when either high forces have to be produced or when lower-threshold motor units fatigue and the bigger units have to pick up the slack. Fatigue is crucial to lower the recruitment threshold of the larger motor units. Larger motor units not only have more muscle fibers that won't grow unless they get recruited, they also have more powerful fast-twitch muscle fibers, which have considerably more potential to grow than slow-twitch muscle fibers. So unless you train with a weight that's heavy enough to recruit all muscle fibers from the start, which requires a weight around your ~8RM, you need to accumulate neuromuscular fatigue before you can stimulate all muscle fibers maximally. Only when enough fatigue has accumulated that all motor units get recruited, can you likely achieve maximum muscle growth.

So when you take a set to failure, by the end of the set you'll have recruited all motor units, regardless of whether that happened in all ~8 reps from the beginning or only the last ~8 reps at the end, and they'll have performed a similar amount of anaerobic work, albeit over different time frames. Sets with 30% and 80% of 1RM produce a similar amount of glycogen depletion in type I and type II muscle fibers and a similar amount of acute muscle anabolic signaling.



During low-load training to failure (~30% of 1RM), higher threshold motor units are recruited later in the set to help as local muscle fatigue accumulates. In the end, all motor units and their muscle fibers are recruited just like with heavy weight training, only at different time points. Source. However, it's worth noting that by the time the highest-threshold motor units are recruited, the firing rates of lower-threshold motor units may already have decreased, which is part of the reason total muscle force production remains constant, along with neuromuscular fatigue's reduction in the force produced by the motor units when they fire. You're still lifting the same weight after all. If you're interested in a highly detailed model of motor unit firing rates during sustained contractions, have a look at this model.

You can see the effect of fatigue as your movement velocity slowing down as you get fatigued. When muscle fibers must produce very high levels of tension, the large number of actin-myosin cross-bridges that must cycle through attachment and detachment prevent the fiber from contracting rapidly. This mechanical property of muscle tissue gives rise to the famous force-velocity relationship of human muscle tissue illustrated below. Put simply, high force production requires slow movement speed. You cannot lift your 1RM rapidly, for example. The force-velocity relationship continues for isometric contractions – muscle contractions that do not result in movement – and eccentric contractions where your muscles lengthen. Muscles can produce more force during isometric contractions than during concentric ones and even more force during eccentric ones. During free-weight movements, such as bench presses or squats, the eccentric contraction is equal to the downward phase of movement. This is why you can prevent more weight from falling down than you can actually lift. And your muscles produce the most force when you take a weight heavier than your 1RM and you control its descent (negative/supramaximal 1RM). For eccentric contractions, force production capacity increases during faster movements, as a faster eccentric movement is a 'more negative velocity'.

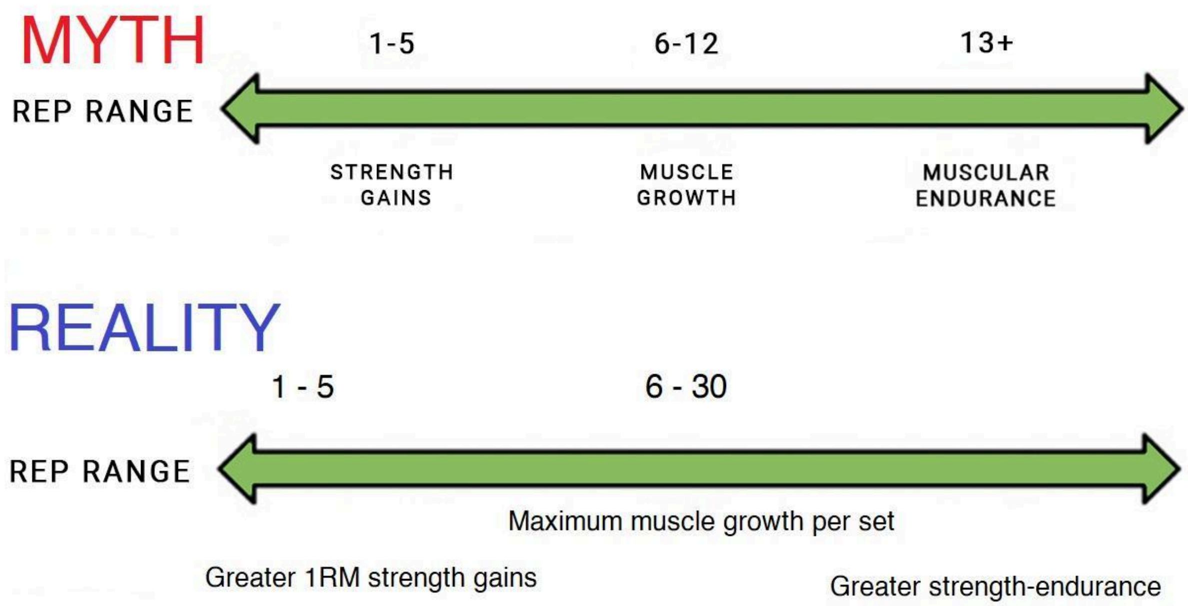


The force-velocity relationship of human skeletal muscle. High force production requires slow movement during concentric contractions and our muscles can produce the most force when they're contracting isometrically or eccentrically.

As it turns out, the maximum movement velocity of the last reps of any set, regardless of weight, is strikingly similar [2]. The last rep you can do of any set looks very much like your 1RM both in terms of movement velocity and exercise technique. As such, the mechanical tension and the growth stimulus of the last reps of any set are probably similar. These are probably the most 'effective reps', as Norwegian strength coach Børge Fagerli dubbed these.

Neuromuscular fatigue can only compensate for low required force outputs up to a point though, so there's a minimum effective training intensity for maximum muscle growth. If you train with weights below ~30% of 1RM, performance may not be limited primarily by force production but rather by metabolic and cardiorespiratory factors, such as energy production and oxygen transport. In this case, you will likely not reach full motor unit recruitment and muscle activation levels will remain too low to stimulate maximum muscle growth.

In sum, on a set per set basis when training close to failure, the 'maximum hypertrophy intensity range' is approximately 30–85% of 1RM, which is roughly equivalent to a range of 5–30 reps. Within this range, any given number of sets produces similar levels of muscle growth. The upper limit of 30 here is very conservative, because some people, especially women, can do as many as 100 reps with 30% of their 1RM for some exercises.



In history's usual pendulum-like nature of idea formation, many people in evidence-based fitness then concluded: "Training intensity doesn't matter at all for muscle growth."

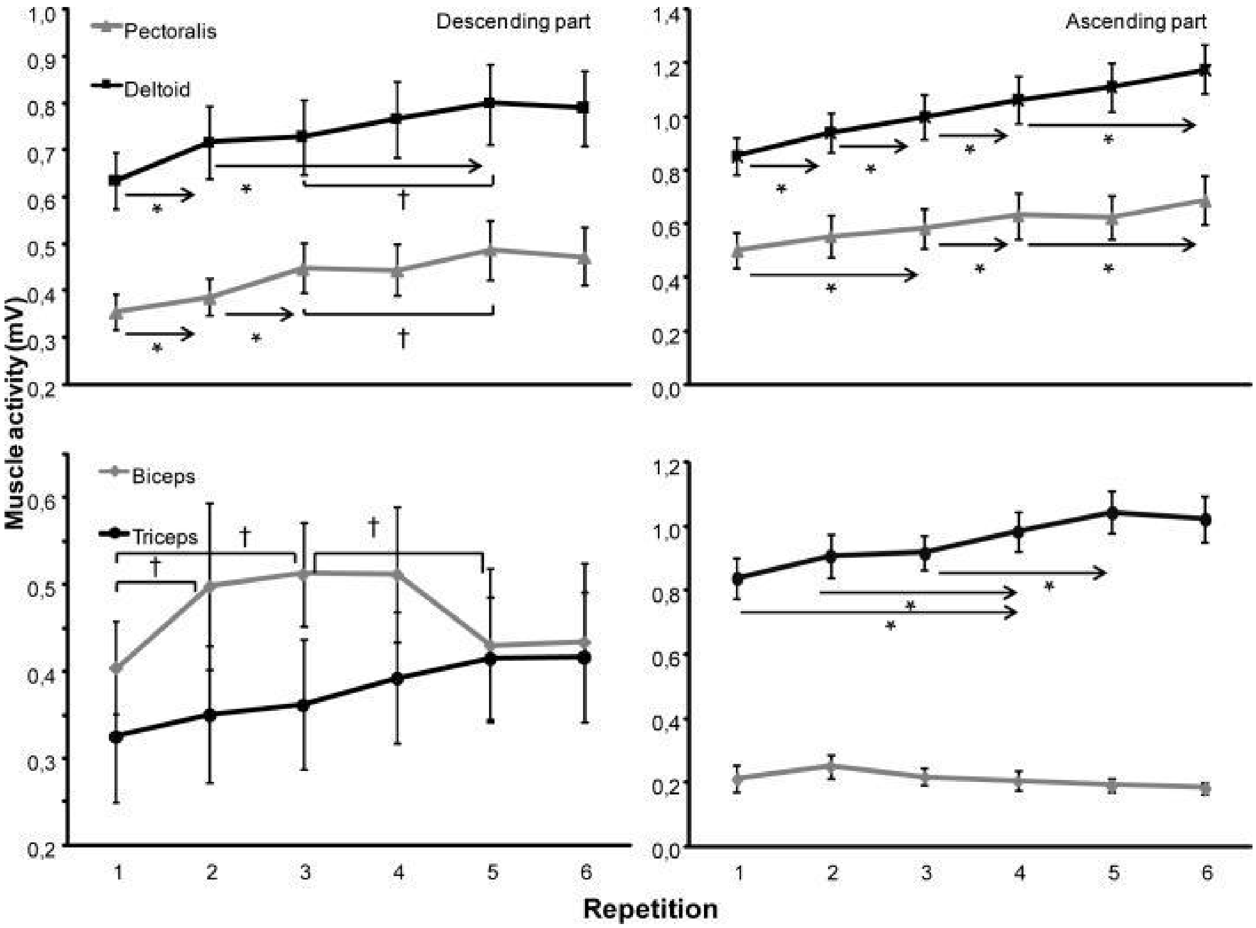
However, there are several considerations to keep in mind when selecting your training intensities, in addition to the weight being heavier than 30% of your 1RM.

Strength vs. size

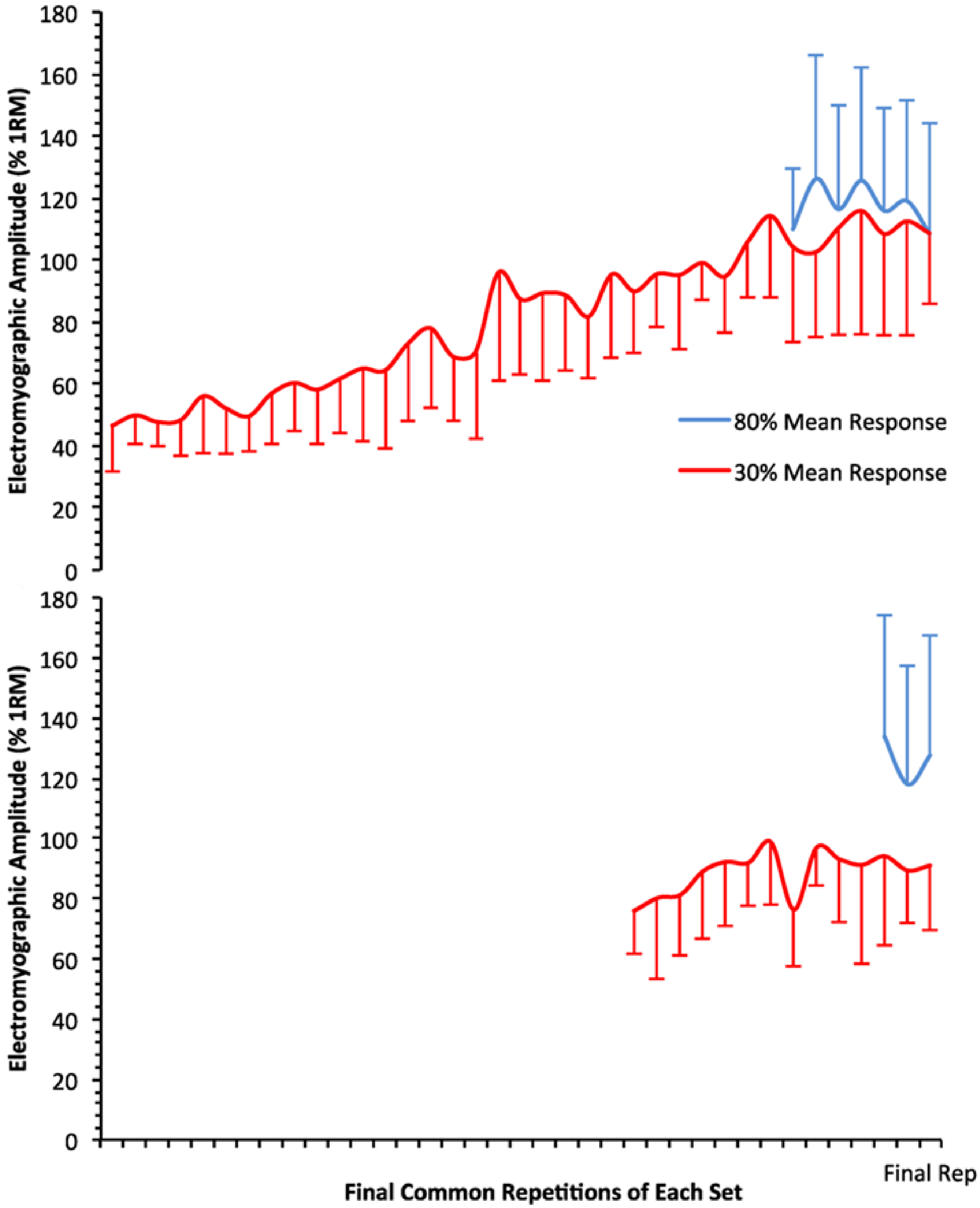
While training intensity is largely irrelevant for muscle growth, it's vital for strength development. Heavy training loads are the single most important part of any training program to build strength [2]. Low-intensity sets can result in just as much muscle growth as higher-intensity sets, but training with light weights is certainly nowhere near as effective for maximal strength development in trained individuals as training with heavy weights. Why is that?

One potential reason is that strength is intensity-specific. If you train in lower rep ranges, you get stronger in lower rep ranges. We commonly associate strength with 1RM strength, but higher-rep training can be more effective to increase your strength-endurance (i.e. strength at higher rep ranges). However, a 2021 meta-analysis and another 2021 systematic review both found that low-rep training is also more effective than high-rep training to improve isometric strength. Since isometric strength is inherently not movement-specific, this means low-rep training must improve some more general neural ability to produce force more than high-rep training.

As you learned in the module on understanding muscle growth, you can think of strength as the sum of neural and morphological force producing properties of muscle tissue. Specifically, muscle cross-sectional area (size) and the recruitment and firing frequency of the muscle fibers (rate coding) are key drivers of force production. Since muscle growth is largely unaffected by exercise intensity, the difference in strength development must come from neural adaptations. It's estimated that even at full motor unit recruitment, muscle force production can still increase 4-10 times by increasing its firing frequency. At intensities above ~85%, full motor unit recruitment occurs from the very first rep of a set [2]. At that point, muscle activation levels are near their maximum, but they can still increase further via increases in rate coding: while all muscle fibers are already recruited, they can be activated more rapidly in succession to produce more force. For example, in strength trained men, muscle activation levels continue to increase every repetition throughout a 6RM bench press set [2] (see data below). During 6RM squats too, muscle activity levels increase all the way up to at least the 4th rep and sometimes all the way to the last rep.

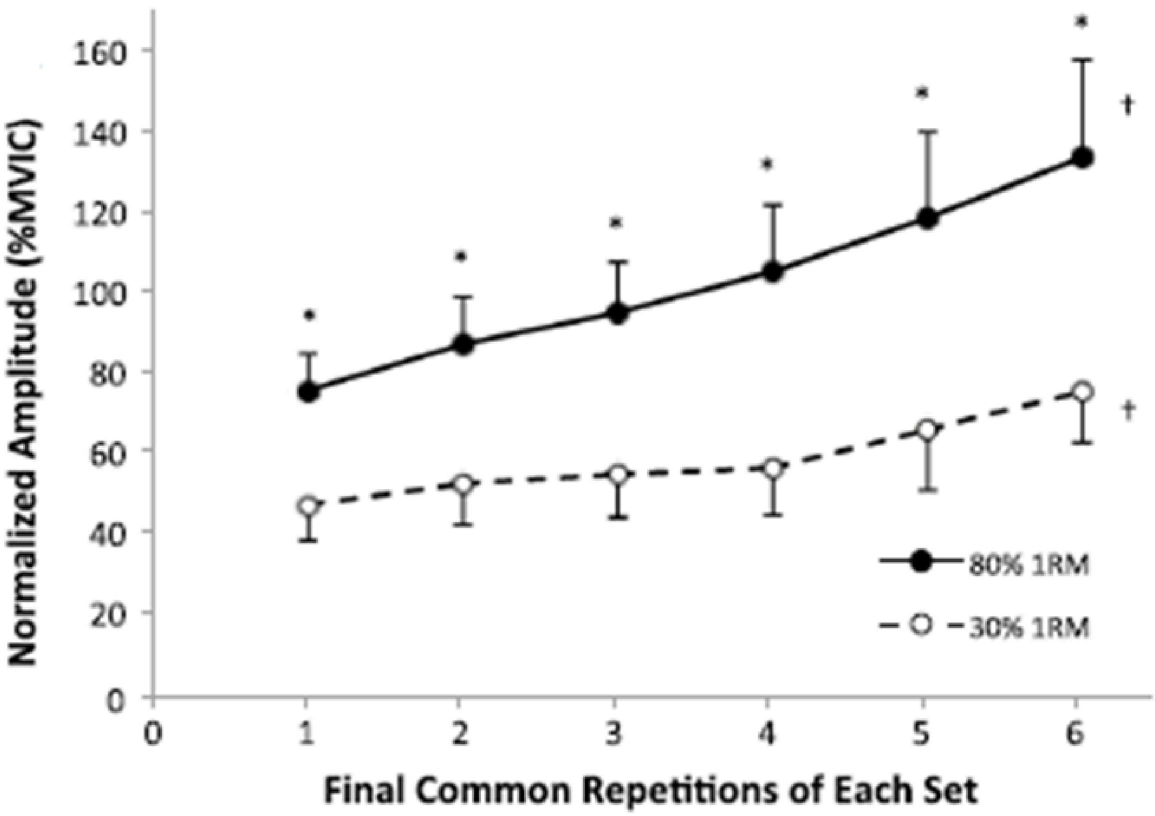


When training with lower intensities, muscle activation levels start much lower, as not all motor units are recruited at first. Muscle activation then rises along with recruitment across the set, as fatigue decreases the recruitment threshold of the larger motor units in line with the diminishing force production capacity of the active motor units. Basically, the larger motor units kick in to help when the little ones get tired. However, fatigue also decreases the firing frequency of motor units or even have them cease firing altogether, limiting total simultaneous motor unit recruitment, so muscle activation levels near the end of a low intensity set still typically do not rival those achieved with higher intensities and the highest-threshold motor units probably don't achieve maximal firing rates unless the muscle has to produce near-maximal levels of force. For example, when strength-trained men squat to failure in the Smith machine with 50% of 1RM, they don't reach the same peak muscle activation in the quads as with 90% of 1RM. In fact, they barely reach the peak muscle activation level of a very submaximal set with 70% of 1RM. Strength-trained men leg pressing to complete concentric failure also do not reach nearly the same peak or average muscle activation levels with 30% as with 75% of 1RM. Similarly, untrained men performing leg extensions to failure with 50% and 70% of their 1RM only barely reach quadriceps muscle activation levels at the end of the set with 50% that they achieve from the very first rep with 70%. To give you an idea of how muscle activation levels develop across sets with low and high intensity exercise to failure, see the graph on the next page. The graph shows muscle activity levels across 2 sets of dumbbell curls to failure with an intensity of 30% and 80%. Even the last repetitions performed with 30% barely rival the first reps performed with 80% and only during the first set. (This graph also nicely illustrates how noisy electromyography (EMG) data is, even when averaged out.)



Muscle activity across the first (top) and second (bottom) set of dumbbell curls performed to failure with 80% vs. 30% of 1RM. [Source]

The following graph shows the same data for the final 6 reps of a set of leg extensions. Here, the final repetitions with 30% do rival the first with 80%, but both peak and average muscle activation levels are clearly higher with 80% than with 30% at every time point (84%–127% difference in EMG amplitude).



Muscle activity during a set of leg extensions with 80% vs. 30% of 1RM. [Source]

In contrast, [muscle activation levels during a bench press set to failure at 8, 10 or 12RM are very similar].

Optional technical sidebar:

how muscle activity is measured by electromyography (EMG)

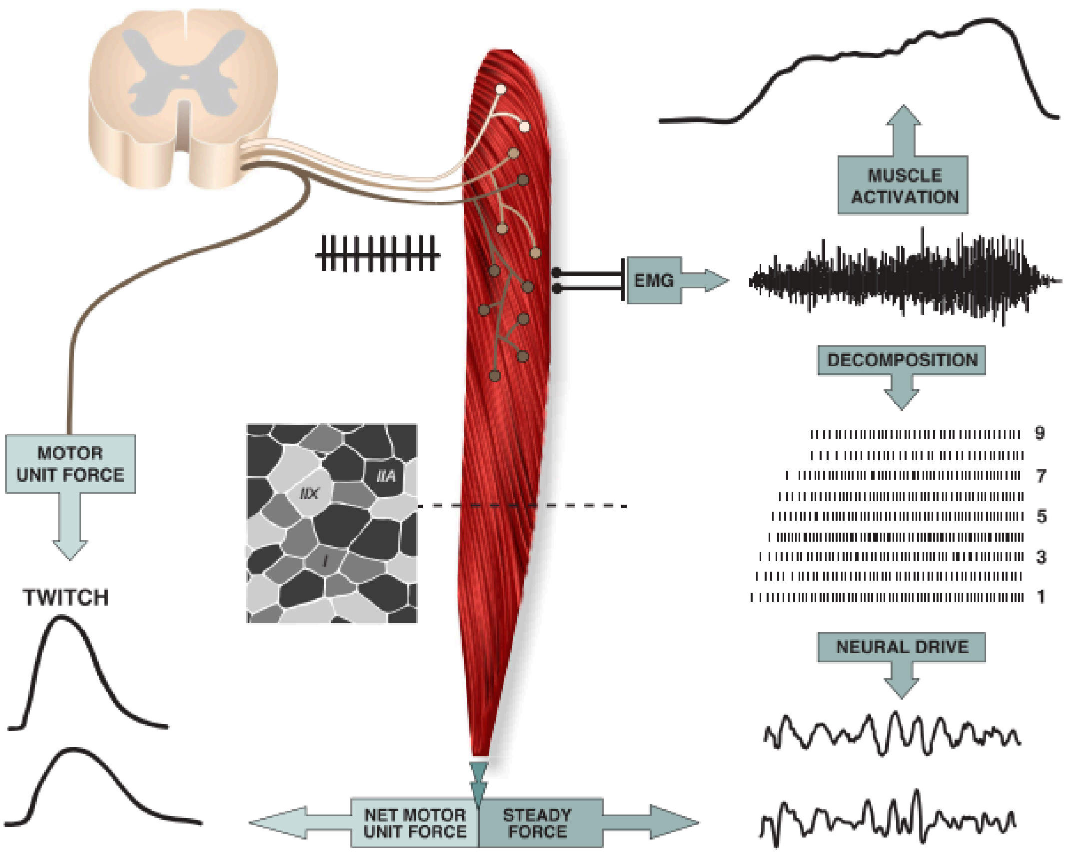


Fig. 1. The force exerted by muscle depends on the characteristics of the activated motor units. In response to synaptic input from descending pathways and peripheral sensory receptors, motor neurons located in the ventral horn of the spinal cord or brain stem generate action potentials that are transmitted along motor axons to muscle fibers and subsequently activate the contractile proteins. The muscle image represents the orientation of the fascicles along the length of the muscle with the distal attachment at the bottom of the image and the muscle fibers attaching to superficial and deep aponeuroses. The forces produced by the activated muscle fibers are transmitted via associated connective tissues to the aponeuroses and then exert a pulling force on the skeleton. The cross-section through the muscle (left of muscle) shows the mosaic pattern of intermingling muscle fibers with different myosin heavy chain isoforms as identified by histochemical assays (only types I, IIA, and IIX are shown). The motor unit force indicates the twitch force exerted by a single motor unit in response to a single stimulus, whereas the net motor unit force indicates the attenuating influence of the surrounding tissues on the motor unit twitch force. The activation signal received by the muscle during a voluntary contraction can be recorded as an interference EMG signal that is either rectified and integrated to provide an index of muscle activation or decomposed into the discharge times of individual motor units (9 are shown) to derive a key control signal for muscle activation. The decomposition of surface EMG recordings into single motor unit activity is most effectively accomplished with high-density surface electrodes (16). The control signal derived from the decomposed signal can be estimated from the cumulative train of action potentials discharged by concurrently active motor units (17). Note the similarity in fluctuations in the control signal derived from the motor unit discharge times and the force fluctuations during a steady submaximal contraction (15).

Source

Since low intensity sets never cause maximal muscle activity due to fatigue preventing full simultaneous recruitment, they do not stimulate the nervous system to adapt as much as maximal weights do. Higher-intensity training can stimulate greater increases in voluntary activation than lower-intensity training, though this may be an early phase adaptation, after which changes in intermuscular coordination are a more important neural adaptation for continued strength development [2, 3]. Regardless of the precise mechanism, training intensity correlates with strength development and rate of force development: heavier weights lead to greater strength development [2, 3, 4]. Maximal strength development is seen at 100% of 1RM, presumably because muscle activity levels cannot increase further at that point: supramaximal training with eccentric overloading at 150% of 1RM does not improve strength development further.

Even if you don't care about strength per se, it's possible that over the long run, greater strength may translate into greater muscle growth. Strength development is accompanied with increased muscle activity levels during exercise [2, 3], though this may be exercise-specific, as muscle activity levels during maximum force production don't seem to increase anymore past the novice stages of training. Higher levels of muscle activation and force production should correspond with increased levels of mechanical tension in the muscle. In support of this theory, Carvalho et al. (2020) found 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, despite gaining less muscle during the strength phase. This suggests getting stronger on exercises may improve their ability to build muscle.

One outlying study has also found that high-intensity training may directly improve muscle growth in well-trained lifters. Magine et al. (2015) found that strength-trained individuals developed more strength and more muscle mass when performing 4 sets with 90% and a 3-minute rest interval compared with 70% and a one-minute rest over the course of a 2.5-month study. The subjects' diets were tracked, a preparatory training phase was implemented to avoid confounding effects of the prior training program, muscle mass was measured via both DXA and ultrasonography at several locations and the subjects were legitimately intermediate level lifters with a pre-study average 1RM bench press of 235 lb (107 kg) at 198 lb (90 kg). The absolute differences in muscle growth weren't major though and may be confounded by the greater rest interval in the 90% group (see the course topic on rest intervals).

Another reason strength development may benefit those solely interested in muscle growth is easier progressive overload. If you don't gain much strength, it's difficult to achieve progressive overload in your program, which makes it difficult to track progress and determine if what you're doing is working. (We'll discuss progressive overload in more detail in the course module on periodization.)

The benefits of higher intensity work for strength development depend on your training experience. On average in the literature, trained individuals gain more strength when training at higher training intensities, whereas for untrained individuals the data are unclear. In novice trainees, multiple studies have found similar strength gains regardless of training intensity [2, 3, 4]. Beginners don't yet require maximal muscle activity levels to maximize strength development. In beginners, many training variables are still irrelevant, because the adaptation process is so general that any kind of sufficiently intensive exercise can maximize muscular adaptations for the first weeks. As you get more advanced, however, your muscles both require greater stresses to continue adapting and are also capable of generating greater stresses. Advanced trainees can achieve higher levels of muscle activity during high-intensity strength training than lesser trained individuals. Thus, the required level of muscle activity and associated training intensity to keep gaining strength go up with training experience.

Total volume

If heavy loads are best for strength, should we all train heavy to maximize strength and size gains simultaneously? No. At very high training intensities (~90-100% 1RM), you may be unable to accumulate enough volume for optimal muscle hypertrophy, unless you perform many sets. While mechanical tension may be high with such heavy weights, the time under tension may not suffice to stimulate maximal muscle growth compared to lighter sets. For example, research found that when your leg training program consists of nothing but 12 sets of squats a week, performing only 3-5 reps per set achieves less muscle growth than performing sets of 13-15 or 23-25 reps. Likewise, performing up to 5 1RM attempts for a muscle per workout is quite effective for strength development but will not give you the same muscle growth as performing 4 sets of 8-12 reps [2]. More generally, sets of 2-4 reps don't stimulate as much muscle growth as sets of 8-12 reps, even though they stimulate more 1RM strength development.

As such, when you incorporate intensities higher than 5RM or 85% of 1RM in a program, for maximum muscle growth you have to add sets or implement other training techniques to reach a similar total tonnage [2] as you'd get with 5RM or 85% of 1RM loads. In practice, you probably don't want to bother with calculating total tonnage (weight × reps × sets) and it's easier to ensure you're staying at 4+ reps per planned set for compound exercises and 6+ reps for isolation exercises. So if you increased the load of 3 sets of bench presses from an 80% to a 90% intensity, you'd still want to perform a total of 12 or more reps for maximum muscle growth. In the advanced training techniques module, we'll discuss how reverse pyramiding is a very effective way to ensure you reach enough total training tonnage for muscle growth without having to add sets.

Fatigue

Many people intuitively equate light weights with easy, but if anyone tells you high rep sets are less fatiguing than low rep sets, you know they've never seriously tried high-rep work. High-rep work is brutal, especially during compound exercises like squats. It feels like you're doing cardio and strength training at the same time. Given the same proximity to failure, lower intensity work results in greater loss of muscle force production and perceived exertion-discomfort [2] and some of this extra fatigue may be in the central nervous system.

Why are lower training intensities more fatiguing? Let's take a set to failure at an intensity of 95% vs. 30%. At 95%, most people can only complete 2 reps. So the level of fatigue is such that they cannot lift their 2RM anymore. That doesn't say much. On a bad day, someone may not be able to lift their 2RM even though they haven't experienced any muscular fatigue yet. In contrast, after a 30RM set, you're so fatigued that you can't even lift your 30RM anymore, let alone your 2RM.

Moreover, the lower the intensity, the greater the total tonnage you lift in the set. If we assume a 100 kg 1RM, total tonnage after the 2RM is only 95 kg × 2 = 190 kg. After the 30RM, it's 30 kg × 30 = 900 kg. So your muscles did over 4 times more physical work.

You may think the greater fatigue after lower intensity sets is mostly acute in the form of metabolic stress. However, lower intensity work also takes longer to recover from than high intensity work [2]. It seems that regardless of what caused the fatigue, the recovery time is similar.

The greater work caused by lower intensity work is a major downside. Acutely, it will reduce performance in the rest of the session. You could compensate for that by performing more sets, but the problem chronically is that you'll have trouble recovering from this. Thus, the greater fatigue caused by lower intensity work prevents it from being suitable as a default training strategy.

Connective tissue recovery

You may wonder if there's ever any reason to include low intensity work in a program considering it's particularly fatiguing. There is one very good reason: to spare your joints. Your tendons can increase in size and stiffness along with your muscles [2]. However, the minimum intensity for maximum tendon adaptations is higher than that for muscle growth [2, 3, 4]. Many types of exercise do not induce meaningful increases in tendon size, only tendon stiffness. For maximum tendon adaptations, an intensity above 70% of maximum voluntary contraction is required, which should correspond roughly with 70% of 1RM [2, 3].

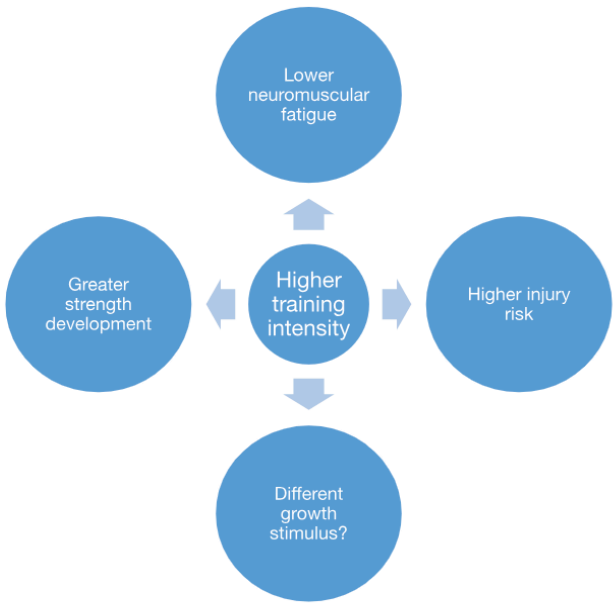
Whether you want to stay above or below this threshold depends on your connective tissue health. If you're injured or are prone to injury, you want to use lower intensities to avoid overloading the tendon. In the long-term, however, you also want to make sure you incorporate heavy loading to strengthen your tendons and prevent future injuries, as strong muscles with weak tendons put you at risk for injury. It may also be required for maximum muscle growth, as a given tendon size can probably only support so much muscle mass.

Combining rep ranges

While high and low rep training seem to stimulate equal total muscle growth on a set by set basis, they may do so via slightly different anabolic pathways. High and low rep training activate different cellular growth pathways according to some but not other research. As we'll discuss in the 'interindividual variability' section, very low and very high rep training may also emphasize different muscle fiber types. As a result, some research finds considerable albeit non-significant trends that individuals experience greater muscle growth when training a muscle with a larger variation of repetitions rather than a narrow range of reps [2] and other research finds more total muscle growth when combining high and low rep training than when doing either alone [2]. It's thus advisable to do both high and low rep training for each muscle group. It does not seem to matter if you train the different rep ranges in the same workout or if you have days with different rep targets.

Conclusion on training intensity

Overall, on a set per set basis taken to failure, muscle growth is similar across ~30-90% of 1RM. Heavier weights are much better for maximal strength development in trained lifters, but if you train with weights so heavy you can only lift them for 1-4 reps, you will have to perform additional sets to compensate for the reduced time under tension. Training intensity also significantly influences your injury risk and neuromuscular fatigue.



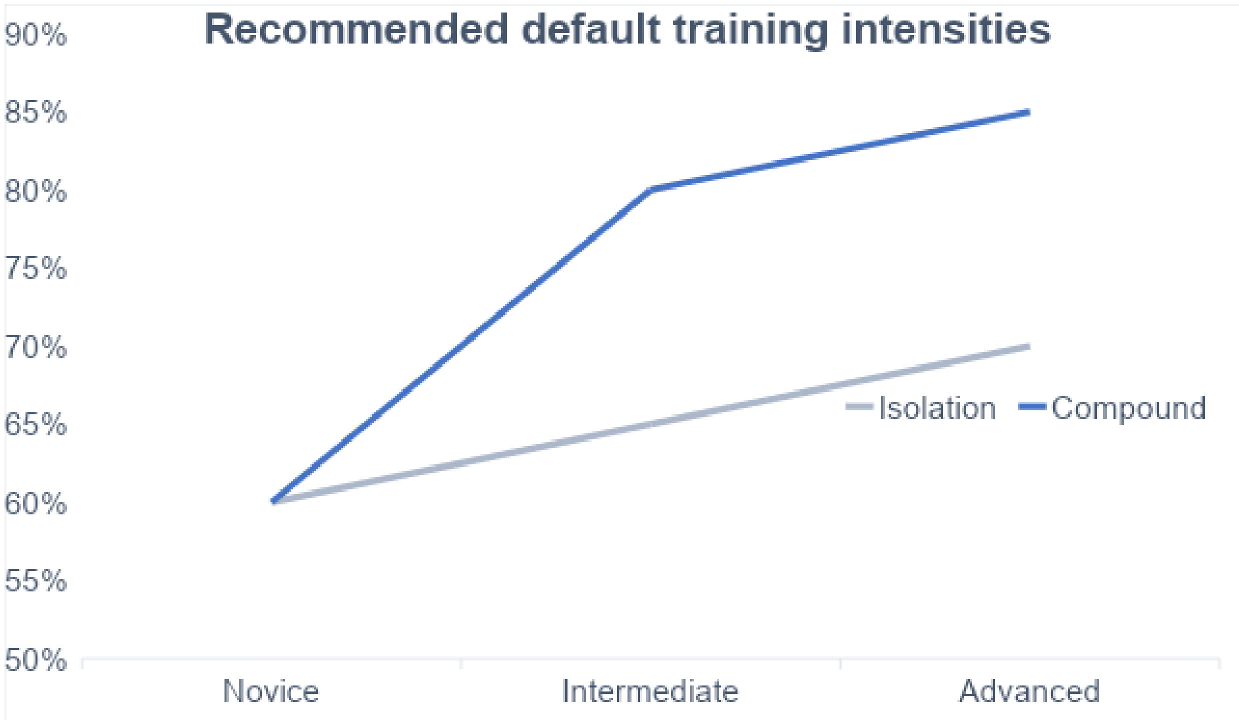
The effects of training with a higher training intensity.

In practice, untrained individuals have little to gain from training with more than 60% of their 1RM. The optimal training intensity rises relatively quickly to 70% of 1RM to support greater strength development and tendon growth. Advanced trainees may benefit from incorporating 85-90% intensity work in their program to facilitate continued strength development and progressive overload.

Most trainees beyond the novice level should generally employ both higher and lower rep training for each muscle group, as they may stimulate slightly different anabolic growth pathways.

Certain exercises lend themselves better to higher-intensity work than others. In general, multi-joint/compound exercises lend themselves well to high-intensity work. Lower-intensity sets can be problematic for exercises like squats due to the high cardiovascular stress that can interfere with technique. Front squats are notoriously poorly suited for high-rep training. Due to the constant tension in the upper body required to uphold the barbell on the shoulders, at higher reps the upper body can fatigue before the lower body does. Moreover, the bar position makes it difficult to breathe. In contrast, single-joint/isolation exercises typically lend themselves very well to high-rep work but not low-rep work, as technique breakdown is very common. For example, try doing a lateral raise 1RM. It's both injurious and difficult without cheating. These practical considerations should be factored in to program design.

For the above reasons, it makes sense to use different training intensities for compound and isolation exercises in trained individuals. Concretely, we recommend the following default training intensities as a function of how advanced the target musculature is and whether it's an isolation or compound exercise. Later on we'll go into how exactly to determine whether someone is intermediate or advanced.



Interindividual variability

So, what does this mean in terms of how many reps you should do each set? Most programs prescribe a fixed number of repetitions to perform, such as 4 sets of 12 reps, or even a fixed weight/intensity and repetitions, such as 4 sets of 12 reps at 65% of 1RM. Prescribing a fixed number of repetitions like this ignores interindividual variability. While for many individuals a 70% intensity indeed corresponds with a set of 12 reps, some individuals will be able to do far more or fewer reps with that weight. Many physiological characteristics of your muscles make you more suitable for either strength or endurance exercise. You can take advantage of this by training according to your genetic strengths.

Colakoglu et al. (2005) used a remarkably detailed study design to investigate how the effects of training set volume (1 vs. 3 sets) and training intensity (8–12 RM vs. 12–15 RM) differed between people with a different *ACE* genotype. People with the ID or II genotype gained more strength when performing more sets, as most people do, yet people with the ACE DD genotype, which is associated with a greater proportion of fast-twitch muscle fibers and great potential for strength and power sports, did not gain more strength when doing more sets, regardless of training intensity. Moreover, individuals with the opposite ACE II genotype, better suited for endurance, gained more strength with 12–15 RM loads than with 8–12 RM loads. Overall strength development was highest in the order of DD > ID > II, as you'd expect. "These data suggest that *ACE* I-allele might be responsible for better response to high volume, low intensity muscular endurance training while D-allele might be related to better strength development with higher intensity, lower volume resistance training." In other words, people tend to respond favorably to the type of exercise they're genetically good at.

Other research [2] finds even more striking variability in which training intensity and volume result in the greatest strength development and bodyweight gain. What is it that makes a person better at higher vs. lower reps? One muscle characteristic we have a lot of research on is muscle fiber type composition.

There are three different types of muscle fiber worth knowing. In order of increasing contraction speed, force production and fatiguability, you have type I, type IIa, and type IIb fibers. Type I fibers are slow-twitch and type II fibers are fast-twitch. Essentially, type II fibers are the body's hard hitters for short bursts of explosive power, whereas type I fibers have greater stamina for day-to-day and endurance type activities. The following table lists the main characteristics of each muscle fiber type.

	Type I Fibers	Type IIa Fibers	Type IIb Fibers
Contraction Time	Slow	Moderately fast	Very fast
Size of Motor Neuron	Small	Medium	Very large
Resistance to Fatigue	High	Fairly high	Low
Activity Used for	Aerobic	Long-term anaerobic	Short-term anaerobic
Maximum Duration of Use	Hours	< 30 minutes	< 1 minute
Power Produced	Low	Medium	Very high
Mitochondrial Density	High	High	Low
Capillary Density	High	Intermediate	Low
Oxidative Capacity	High	High	Low
Glycolytic Capacity	Low	High	High
Major Storage Fuel	Triglycerides	Creatine phosphate, glycogen	Creatine phosphate, glycogen

Each muscle has a different fiber type composition. Some muscles are fast-twitch dominant; others are slow-twitch dominant. Your fiber type distribution in each muscle is largely genetically determined. Some conversion takes place when you first start strength training, predominantly to an increased proportion of type IIa fibers and a reduced type IIb proportion, but this does not appear to depend much on the specifics of the strength training protocol and the conversion process appears to be largely complete within a few weeks.

The more slow-twitch dominant your muscles are, the better they are at endurance training instead of strength training. For example, the preferred racing distance of elite and sub-elite speed skaters correlates well with their muscle fiber type composition. The α-actinin-3 (ACTN3) gene R577X polymorphism is one of the contributing gene variations in the determination of muscle fiber type composition and athletic status. Elite strength athletes, such as weightlifters and sprinters, typically have very fast-twitch dominant muscles, whereas elite endurance athletes, such as marathon runners, typically have very slow-twitch dominant muscles.

With direct relevance to weight training, your muscle fiber type composition can influence how many reps you can do at any intensity [2, 3]. The more slow-twitch dominant a muscle group is, the more reps it can generally do at a given intensity (% of 1RM). A born sprinter with highly fast-twitch dominant muscles can probably not do as many reps with a certain training intensity as a born endurance athlete with very slow-twitch dominant muscles.

However, your muscle fiber type is only one out of many factors that regulates your individual rep-intensity relation. Terzis et al. (2008) found that muscle fiber type didn't influence how many reps the participants could do at an 85% or 70% intensity. However, another factor did: capillary density. Capillaries are small blood vessels. More blood vessels allow for better blood flow and thereby oxygenation, allowing type I fibers to remain active for longer. Bagley et al. (2017) also found no relation between muscle fiber type composition and fatigability for 30– and 50–rep sets.

Regardless of why exactly a muscle is better at performing higher or lower repetition sets, some studies show that how many reps you do per set can slightly influence the relative muscle growth of slow- vs. fast-twitch fibers [2, 3, 4, 5, 6, 7]. Regular heavy strength training causes preferential type II fiber growth, especially powerlifting type training, whereas high rep training may cause preferential type I fiber growth, especially when there's no muscle relaxation in between reps or the muscle is occluded. However, multiple other studies have not found the expected effect of training intensity on which muscle fibers grow the most. Schuenke et al. (2012), Holloway et al. (2018), Morton et al. (2016) and Lim et al. (2019) found no difference in relative growth rates of type I and type II fibers after training with heavy vs. low loads. Campos et al. (2002) and Mitchell et al. (2012) found trends, but they did not reach statistical significance. Schoenfeld et al. (2020) found that the slow-twitch soleus muscle and the mixed-twitch gastrocnemius grow equally well to high and low rep training, though individual muscle fiber types were not assessed and it was in previously untrained individuals. The Russian literature, on the other hand, is quite clear on the relation between rep volume and fiber type specific growth. Their studies often had the subjects train with constant muscle tension, so it's plausible that preferential slow-twitch muscle fiber growth occurs more reliably when the muscle cannot relax in between reps.

In competitive bodybuilders, equal hypertrophy of type I and II fiber types has been found. In contrast, powerlifters, and Olympic weightlifters show preferential hypertrophy of the type II fibers. This may be the result of their training. Powerlifters and Olympic weightlifters typically spend a relatively large amount of their training at an intensity of 90+%, whereas bodybuilders typically train with more reps per set and often 'keep the tension on the muscle'.

A muscle's fiber type composition also influences how fast it fatigues and recovers, seemingly in particular from strength-endurance type training. More fast-twitch muscles generally suffer more fatigue (loss of force production) during exercise. The type of exercise doesn't appear to matter. Research has found the greater fatiguability of fast-twitch muscle muscles after 30–second Wingate sprints [2], sustained maximal voluntary isometric contractions, very high rep isokinetic leg extensions [2], and a minute of jumping. In line with their greater fatiguability, more fast-twitch muscles also show poorer recovery in the hours after 30–second Wingate sprints, during 1-minute rest interval after 30 RM isokinetic leg extensions and during 5-minute rest intervals after 16 5-second maximal voluntary isometric contractions. In endurance runners, being fast-twitch dominant is also associated with a higher risk of overreaching in response to increased training volumes.

With direct relevance to strength training program design, fast-twitch muscles may fatigue particularly badly after high-rep training. In the days after high-rep strength training, more fast-twitch muscles show a trend to suffer considerably greater loss of force production after training with 30% of 1RM but not with 80% of 1RM. All in all, it seems fast-twitch dominant muscles may respond better to–or at least recover better from–lower-rep training, longer rest intervals and lower set volumes than slow-twitch muscles.

The muscle-specific hypertrophy method

To customize someone's training program to their muscular physiology, it may be beneficial to prescribe training intensities rather than fixed repetition counts. So rather than programming, say, 4 sets of 9 reps at 70% of 1RM, program 4 sets at 70% of 1RM at a given proximity to failure. One individual's reps may go like 15, 13, 11, 10, whereas another's reps may go like 8, 5, 4, 3. These are significantly different training volumes. With this method, you autoregulate the program's repetition training volume based on that individual's genetic strengths. A 2019 systematic review found strength gains tend to be greater in studies using %1RM as a method of determining training intensity than direct repetition maximum approaches, although the review did not control for proximity to failure or training volume.

Prescribing a percentage of 1RM instead of a RM also tends to be well-liked, as people generally like training in rep ranges they're strongest in.

Moreover, the %1RM method controls for certain exercises not being suitable for certain rep ranges. If someone has poor endurance, they may be better off doing sets of 6 at 75% of 1RM rather than forcing themselves to do the expected 10RM.

Here's how you implement the muscle-specific hypertrophy method.

1. After you've created a training split with a certain exercise selection and set volume, the first time you perform each exercise in the program, you plan in a 1–5RM test followed by the regular number of remaining sets, if any, with 50–80% of that weight.
2. Estimate each exercise's 1RM with the Henselmans RM calculator.
3. Determine each exercise's optimal training intensity based on this course's guidelines.
4. Calculate the weight corresponding to that intensity and plan it in for next session.
5. However many reps the trainee can do with that weight becomes the rep target for that exercise in the program.

Example: An advanced male trainee has squats with a set volume of 3 in the program. The first time he performs them, he tries to find his 1–5RM and ends up with 160 × 2 reps. Then he does 2 more sets with 80% of that weight, but the outcome of that isn't relevant for this example. A good training intensity to use in this case is 85%. The Epley

1RM is 171 kg, so 85% of that is 145 kg. Let's say in this program he trains one rep to failure. The second time he does squats in the program, i.e. the next squat workout, he then reps out with 145 kg and he achieves, say, 6 reps. His rep target then becomes 6 for this program, i.e. he aims to complete 6 reps in the first set of each squat workout. Progression from here on will be discussed in the course module on periodization.

Estimating 1RM

To prescribe a percentage of 1RM, you need to know the 1RM. Thus, the first time you perform any workout of a program with the muscle-specific hypertrophy method, you need to find each exercise's 1RM.

A common objection to the muscle-specific hypertrophy method is that only advanced trainees can reliably find their 1RM. That's nonsense. 1RM testing in untrained individuals is done all the time in research and there is a substantial literature that indicates 1RMs can reliably be found for pretty much all exercises even in entirely untrained individuals after familiarization with the exercise [2]. In fact, 1RM testing is much easier in untrained individuals, psychologically speaking. As you learned in the course topic on the optimal training intensity, more advanced trainees can achieve far higher levels of muscle activation. As a result, 1RM attempts are more mentally demanding for advanced lifters than untrained individuals.

That said, it is often safer to perform a 3-5RM and estimate 1RM based on that. Several formulas have been created for this with variable accuracy: see the research overview below. We generally recommend using the Epley formula, sometimes called the Welday formula, as it has been validated in several studies for both the bench press and the squat and for both men and women:

$$\text{Epley estimated 1RM} = \text{weight} \times (1 + \text{repetitions} / 30)$$

Don't like math? Here's a calculator to do the work for you. It also has options for bodyweight exercises, such as chin-ups, and push-ups. When you insert someone's total bodyweight, the calculator will automatically factor in the proportion of bodyweight lifted into the total resistance.

➢ **1RM Calculator**

Equation	Strength-trained populations tested	Exercises tested	1 RM estimate error (+/- kg)
Brzycki	Male division 1 college football players	Back squat	- 4.8
	Strength-trained females	Bench press	+ 10.5
	Collegiate male football players	Bench press	+ 15
	Male division 2 college football players	Bench press	+ 13
Epley / Welday	Male division 1 college football players	Back squat	+ 2.7
	Collegiate male football players	Bench press	+ 2
	Male division 2 college football players	Bench press	+ 1
	Collegiate male football players	Bench press	+ 2

	Strength-trained females	Bench press	+ 2
Lander	Strength-trained females	Bench press	+ 9.7
	Collegiate male football players	Bench press	+ 7
	Male division 2 college football players	Bench press	+ 12
Chapman et al.	Collegiate male football players	Bench press	- 3
Lombardi	Collegiate male football players	Bench press	- 11
Mayhew et al.(1)	Male division 2 college football players	Bench press	- 3
	Collegiate male football players	Bench press	- 3
Mayhew et al.(2)	Collegiate male football players	Bench press	- 1
O'Conner	Collegiate male football players	Bench press	- 8
Slovak	Collegiate male football players	Bench press	- 1
Wathen	Male division 2 college football players	Bench press	+ 1

	Collegiate male football players	Bench Press	+ 2
	Strength-trained females	Bench press	+ 2
Whisenant et al.	Collegiate male football players	Bench press	- 0
Adams	Strength-trained females	Bench press	+ 2
Brown	Strength-trained females	Bench press	- 1.5
Berger	Strength-trained females	Bench press	- 9
Cummings and Finn	Strength-trained females	Bench press	+ 2
Kemmler et al.	Strength-trained females	Bench press	- 2
O'Connor et al.	Strength-trained females	Bench press	- 1
Reynolds et al.	Strength-trained females	Bench press	+ 1
Tucker et al.	Strength-trained females	Bench press	- 0.5

Intensity-load relation testing

After you've found an exercise's 1RM in the first set of each exercise's first workout in the program, you can do another test to get an idea of the muscle's physiological properties: perform as many repetitions as possible with a far lighter load for any remaining sets planned for that exercise. When you know a muscle's performance with a higher and a lower intensity, you get a pretty good idea of which rep range the muscle is strongest in. The combination of a very high and a very low intensity is best to determine a muscle's mechanical properties. For example, if you see an individual can barely do 10 reps with 40% of 1RM, that's a sign the involved muscles may be very fast-twitch dominant, have a low capillary density or for whatever other reason not respond well to high training volumes.

Concretely, the high intensity for our purposes will be the 1-5RM. For the low intensity, we can use the low end of the hypertrophy range: 40% of 1RM. However, in practice it's inconvenient to have to determine 40% of 1RM on the spot in the gym after the 1RM and it's simpler to use the instruction: "perform as many reps as possible with half the weight of your 1–5RM (rounded down)".

For exercises like squats that do not lend themselves well to perform with very high repetitions, you may opt for a mere 20% reduction weight to get a ~70% intensity.

This testing will also give you an idea of the individual's work capacity, which can be further used as a cue of whether the training volume should be adjusted. We will discuss this in more detail in the module on customized program design.

Here's another example of the muscle-specific hypertrophy method in full. Suppose you have an advanced male trainee that trains 3 times per week, alternating between full-body workouts A and B. The first workouts A and B of the program will be test sessions where he finds his 1RM for each exercise and performs his remaining number of planned sets with 20–50% less weight for each exercise. You generally want to do the same number of sets here with the exercise in the same order as you're going to do in the rest of the program, because otherwise you confound the test results by fatigue from other exercises, but performing one set less may be advisable too to save time on what will be a long session and to reduce muscle damage from the novel exercises. Suppose during session A the squat 1RM comes out as 455 lb. As an advanced trainee, let's say you've determined these squats should be done at an 85% intensity. For the next session A, you then prescribe a weight of 455 × 0.85 = ~390 lb for the squats. He then does as many reps as possible with that weight (or goes however close to failure you want him to go, as we'll go into later). However many reps he achieves is then a marker of his optimal volume. You'll get different training volumes for each exercise, in line with the different fiber compositions of the different musculatures involved in the different exercises.

Often, you don't get very surprising numbers. Most people can do 6–10 reps with 80% of their 1RM, for example. However, occasionally you get uncommon results and it's exactly in these individuals that the muscle-specific hypertrophy method shines. There are 2 profiles that stand out in Menno's experience.

1. The very slow-twitch dominant woman that responds better to high rep training–as many as 20–30 reps even–than traditional strength training. This tends to scare coaches, as they think the testing must have gone wrong, so they lower the rep targets. Don't. This is often exactly the person that will benefit greatly from the muscle-specific hypertrophy method.
2. The prototypical strength-power athlete, often male with great genetic potential, that thrives on very low rep work and just burns out or gets injured doing a lot of volume.

The muscle-specific hypertrophy method is not required to make a program effective. In terms of pure muscle growth and strength development, it will likely only slightly outperform fixed rep targets over the long run and only in muscles with a non-standard physiology. You're also not obliged to use it in the exam. As we discussed earlier, the majority of research finds similar muscle growth across a wide range of intensities on average. Autoregulating repetition volumes with the muscle-specific hypertrophy method for individuals with a typical physiology thus provides little extra direct result. It is only potentially useful for individuals or muscles with non-standard physiology.

That said, the method is also very informative to use if you are willing to do a bit of extra work with the tests. After the test session, you have an idea of the individual's exact strength level for each exercise, you have an estimate of each muscle's work capacity and you have an idea of whether they're better suited for lower or higher repetitions and training volumes.

The tests also tell you many other things about a person. Here are some examples from Menno's experience.

- If they don't know how to work up to a 1RM, they're evidently not very experienced.
- If they're uncomfortable going up to 1–5RM weights, their technique probably needs work.
- If they ask you a gazillion questions about how many warm-up sets to perform for a 1RM, how to round off the weights when they take 50% of a weight and other technical questions like this, they're often overanalyzers and it's good to have them learn to autoregulate and 'just do it'.
- If someone is much stronger at high than low intensities for technical exercises, like squatting 100 × 1 and 80 × 4, a technique check is advisable, because there's a good chance they're sacrificing form for weight.

- If their reps increase across sets with the same weight, like squatting 100 × 1, 80 × 8,9,11, they're probably not training very hard. Reps across sets should typically only ever go down, as muscles should fatigue from intensive training.
- If you see a certain maximum rep number come up all the time, that can mean they have a mental block. Many people, especially men, are reluctant to go above ~12 reps per set, possibly implicitly because they think hypertrophy range ends there. These individuals benefit from learning to autoregulate their programs and train harder.

A simpler method

If the muscle-specific hypertrophy methods sounds overly complicated to you, you can simply set fixed rep targets based on the population averages of the intensity-load relation. Instead of prescribing a weight based on the preferred training intensity (% of 1RM) to find someone's rep targets, you can prescribe the following rep targets directly. The table below from a 2023 meta-regression by Nuzzo et al. lists which rep target you can prescribe based on which intensity you would prescribe with the muscle-specific hypertrophy method. There's a separate table for bench presses and leg presses, because these exercises have been found to have significantly different intensity-load relationships than other exercises.

For example, if you have an intermediate trainee for whom you want to set their rep targets with 80% and 65% of 1RM for pulldowns (a compound exercise) and lateral raises (an isolation exercise), you can forego the whole rep target testing and just directly prescribe them rep targets of 10 for the pulldowns and 17 for the lateral raises.

In practice, you may want to customize these numbers a bit based on which rep targets each exercise is better technically suited for. Squats, for example, can turn into semi-cardio for many people if you go with rep targets over 10.

For most individuals, this method will likely provide similar results as the muscle-specific hypertrophy method. However, you do lose out on the information and customization you would get from the 1RM and rep target testing.

	Reps performed for…		
Intensity (%1RM)	The bench press	The leg press	All other exercises
95%	3	7	3
90%	4	9	5
85%	6	11	7
80%	9	13	10
75%	12	16	12
70%	14	19	15
65%	17	23	17
60%	19	27	20
55%	23	32	22
50%	27	37	26
45%	33	43	30
40%	40	50	36
35%	51	58	42
30%	63	67	51

How many reps people can perform on average for bench presses, leg presses and other exercises. Source

Now that you understand how training intensity affects – or often does not affect – muscle growth, we can discuss training volume.

Training volume

Training volume is a measure of the total amount of work done in a training session. The following definitions of training volume are used in the scientific literature.

- Training volume load (sometimes called total work) = sets × reps × weight
- Repetition volume = sets × reps
- Set volume = number of sets

Example: 2 sets of 9 reps of squats with 100 kg have a total training workload of 2 × 9 × 100 = 1800 kg, a repetition volume of 2 × 9 = 18 reps and a set volume of 2.

When scientists speak of ‘training volume’, they are often referring to training volume load. However, volume load often has little practical importance, as it’s strongly influenced by the person’s strength level. If person A performs 4 sets of 7 squats with 200 lb., this person’s training load is 5600 lb. If another person can do the same workout with 220 lb., that person’s training load is 10% higher. Yet the stimulation of the muscles is very similar for both persons.

The same problem arises when comparing different exercises. Squats rival or beat leg presses for muscle growth, as we’ll discuss in the topic on exercise selection, yet tonnage and therefore total work done will almost always be substantially higher in leg press workouts because you can move more weight.

Add to that all other biomechanical, morphological and neural factors that change someone’s strength even with the same amount of muscle mass performing the same amount of internal work, and it’s clear that training load often doesn’t say much about the stimulus for muscle growth.

Repetition volume is more useful, since by removing the training load from the equation you remove the confounder of strength. However, as we discussed in the course topic on training intensity, between roughly 30 and 90% of 1RM, training intensity often doesn't greatly affect the amount of muscle growth stimulated by the training.

Therefore, we should use set volume as the primary measure of training volume in most circumstances. Total sets correlate more strongly than total work or repetition volume with muscle growth when you train close to failure within the range of 30-90% of 1RM. Set volume is by far the most important program variable for muscle growth [2].

We can simplify our volume metric further by limiting it to sets per muscle group *per week*, because in most studies a given weekly set volume results in similar strength and size gains regardless of training frequency. There is evidence of a ceiling effect per workout rather than per week, as we'll discuss in the subsequent section on training frequency, but most researchers quantify volume on a weekly basis for simplicity's sake.

Other programming methods can benefit from monitoring training volume in different ways. For example, you will learn about the myo-reps method, which monitors 'effective reps', in the advanced training techniques topic. However, weekly set volume per muscle group is a simple and effective way to quantify training volume with strong scientific support, so this is what we'll use.

Importantly, training volume should always be monitored per muscle group. As you've learned in the topic on strength training adaptations, muscle hypertrophy is primarily a local, intrinsic process, so we need to program the volume for each muscle group individually. In the exercise selection module, we'll discuss how much each exercise trains each muscle group.

So we've determined our measure of training volume: **number of training sets per muscle group per week.** The next step is: how much volume is best?

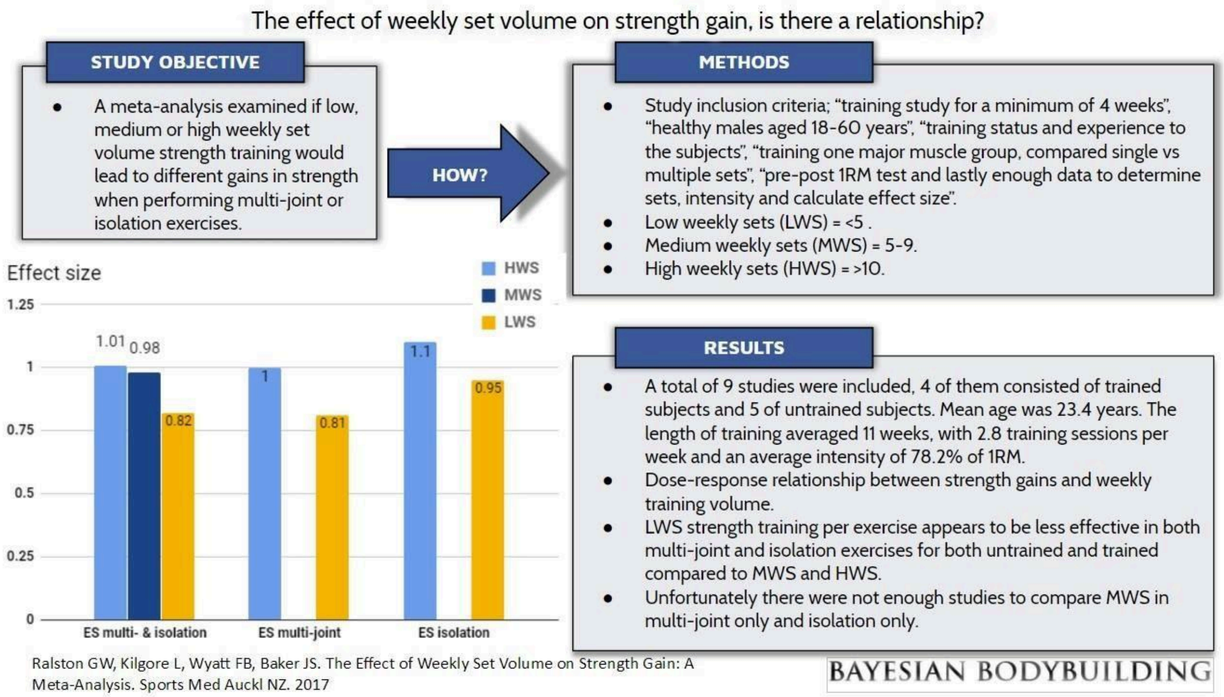
The optimal number of sets per week per muscle

Multiple meta-analyses have been conducted that looked at studies equal in all regards except the number of work sets per muscle group. In the overall literature, these meta-analyses find significant benefits for muscle growth up to at least 10 sets per week per muscle group and likely up to 20 sets with some evidence up to 30 sets. While higher volumes tend to produce better gains than lower volumes, there are there are diminishing returns to training volume [2, 3]. Every additional set you do results in an increasingly smaller additional benefit for your progress. There are 2 main reasons for the diminishing returns to exercise volume.

1. There's a maximum amount of muscular adaptation the body will realize from a single workout or week of training. There's a limit to the body's ability to recover from training stress and to remodel its structures. After a certain level of training stress, you exceed the body's capacity to further adapt to the stress and further stress can even be detrimental. As Lee Haney famously said: "Exercise to stimulate, not to annihilate." (Overtraining will be covered in the course topic on periodization.) From an evolutionary point of view, it makes sense that there is a cap on muscle growth, akin to the muscle-full effect, to prevent excessive investment in energetically costly muscle mass.
2. Fatigue impacts the quality of subsequent training. Specifically, muscle damage limits your body's ability to further activate muscle tissue.

Strength vs. size

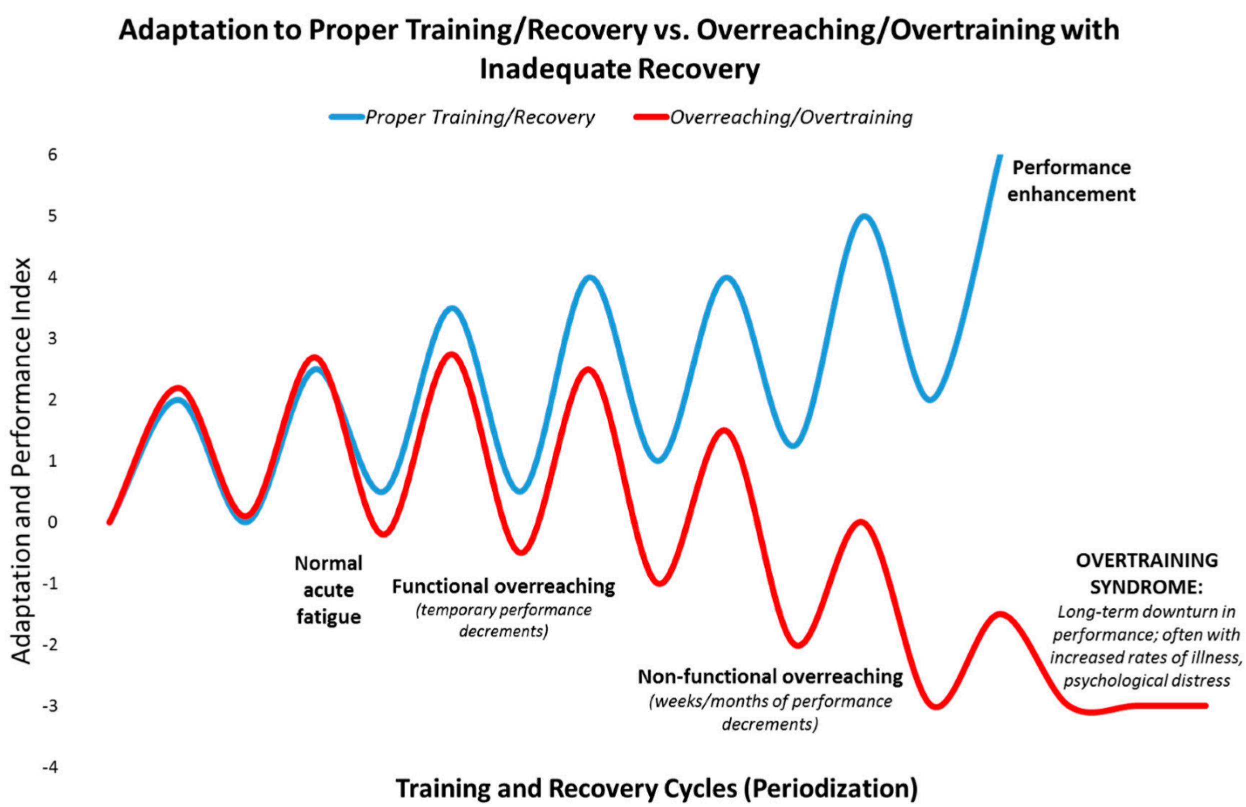
For strength development, the additional gains from higher training volumes are notably lower than for muscle hypertrophy. In the latest meta-analysis on strength development, you can see the diminishing start well before the 10 sets per week per exercise mark. Note though that this is sets per exercise, not per muscle group. Since most muscle groups are trained with several exercises in typical training programs, the volume per muscle group will be substantially higher than per exercise. Also, few data on medium training volumes were available, so you don't want to read too much into the exact dose-response curve, but it's clearly less steep than the dose-response curve for muscle growth.



In other words, volume is more important for muscle growth than for strength development.

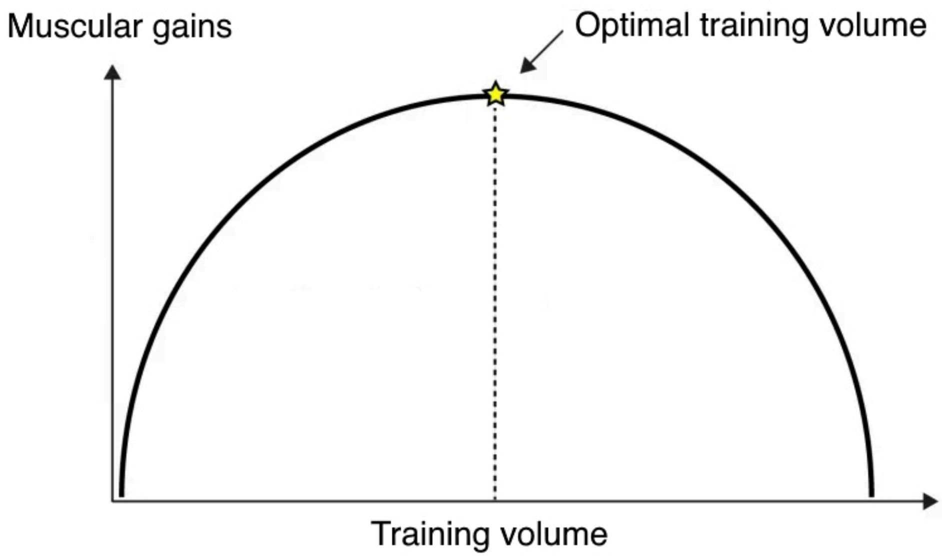
Overreaching and the optimal volume

Not only are there diminishing returns to your training volume, at some point additional volume becomes detrimental. You will exceed your body's capacity to recover from the training stress and your body becomes incapable of adapting before your next training session. This is called overreaching and ultimately can lead to overtraining syndrome, as illustrated below.



Source

Since we know there's a minimum effective volume, below which you don't make any gains, and a maximum recoverable volume, above which you overreach, there must be an optimum volume in the middle. Training volume should theoretically have an inverted U-shaped relationship with strength and size gains, as illustrated below.



Theoretically, training volume should have an inverted U-curve relationship with muscle hypertrophy and strength development.

Based on the above meta-analyses and theory, we can roughly say that for many people, the optimal training volume is somewhere in the range of 10 to 20 sets per muscle group per week. However, these numbers are based on averages from the total literature.

Hardgainers & individual variance

The optimum volume varies considerably per study and individual. Multiple studies have found optimum volumes outside of the 10-20 set range, most likely because the training volume sweet spot is individual. Each individual has an optimum training volume, compared to which doing less or more both result in worse results [2, 3, 4]. The strongest support for the individual optimum comes from research within individuals where one leg is trained with a higher volume than the other: some people gain more muscle in the leg trained with higher volume, whereas other people gain more muscle in the leg trained with less volume. In other words, each individual has its own volume sweet spot.

In fact, each individual muscle of each individual person can theoretically have its own volume sweet spot, but different muscles within the same individual tend to respond very similarly to different training volumes. So most of the variance seems to be between individuals. Within each individual, the optimal training volume tends to be similar for each muscle group, assuming each muscle group is similarly advanced.

So some people have an easier time gaining muscle than others. What if you have a really hard time putting on muscle? Some research has looked at training non-responders, informally called hardgainers. It turns out that so-called non-responders generally just don't respond significantly to the specific training stimulus of the study, but they do respond to other, generally more intensive, training programs. Higher training volumes reduce the number of non-responders for both strength training [2, 3, 4] and endurance training [2]. Training non-responsiveness and training volume seem to function similarly to anabolic resistance and protein intake: some people need a more intense stimulus for the body to gain muscle. (See the age-specific programming module for more details on anabolic resistance.) True non-responsiveness to exercise or a physical inability to build muscle seems to be exceptionally rare [2].

To recap, most people make better progress on higher training volumes, but sometimes higher volumes result in worse progress due to overreaching. How do you know where the optimum lies? The following factors likely determine what the optimal volume is for an individual.

Training status

The optimum volume is likely different for trained individuals than for untrained individuals. A meta-analysis by Rhea et al. (2003) found that the optimal volume for strength development increases with training status, as illustrated below.

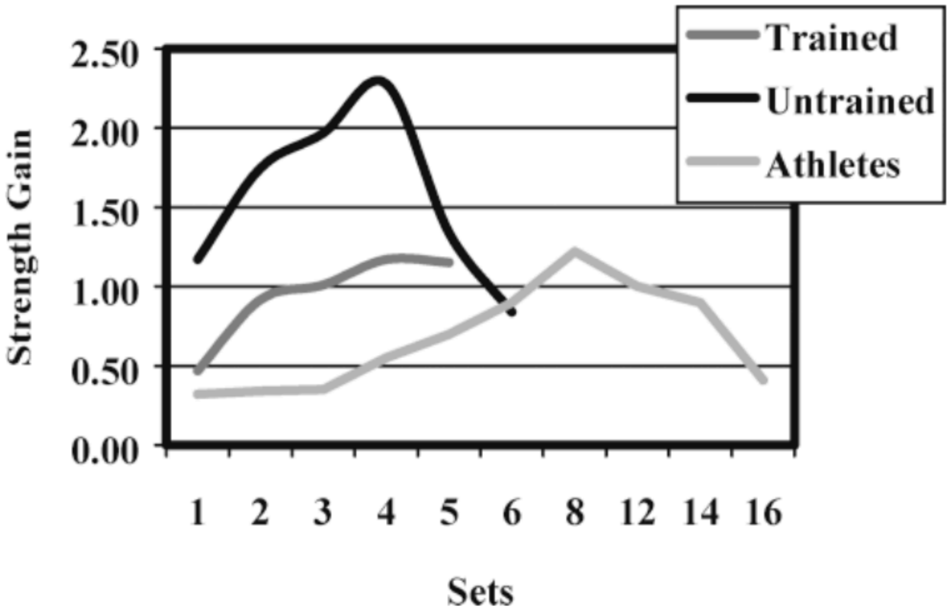
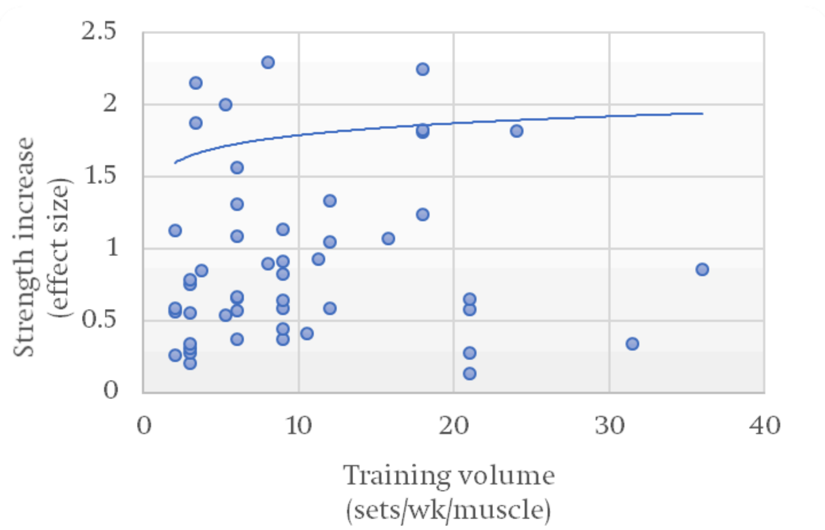


Figure 3. Volume of training: the number of sets performed (per muscle group) during each workout.

It makes sense that the more advanced you are, the higher your optimal training volume likely is. Trained individuals are more resistant to muscle damage than untrained individuals [2], suffer less acute fatigue from a given workout and they recover faster from a given workout than when they were less trained [2]. Advanced trainees sometimes also show a blunted hormonal-anabolic response to a given training volume. As a result, a higher training stress can likely be tolerated and is likely required to stimulate further training adaptations. A 2020 meta-analysis found that just a single set to failure per week generally increases muscle strength in novice level lifters, whereas a series of 2021 studies found that powerlifters generally need to perform at least 3 to 6 sets per exercise per week to gain any further strength.

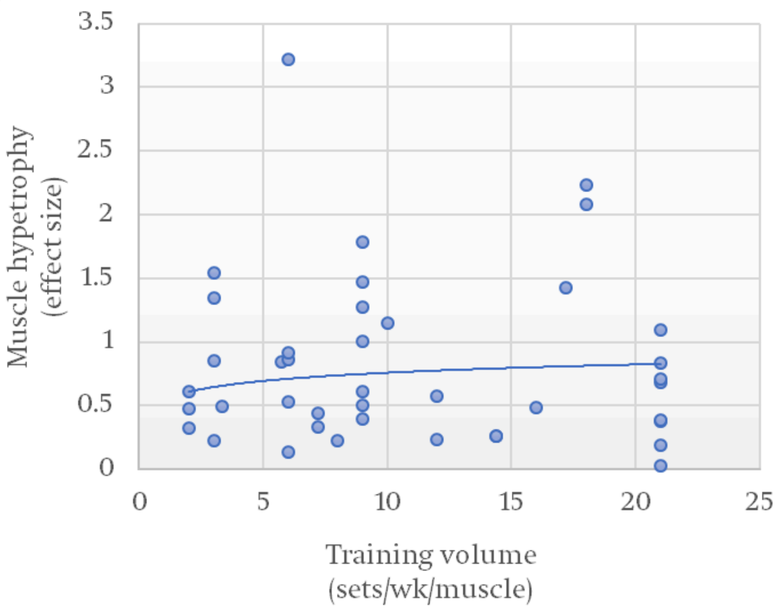
To determine the optimal average training volume for untrained vs. trained lifters, we plotted the effect sizes of muscle growth and strength development (usually 1RM) against the average weekly set volume for the target muscle group of all studies in the literature in the following graphs. We added a best-fit logarithmic trendline in each graph to illustrate the average trend. A tabular overview of the studies including weekly set volumes over 10 sets can be found here. We haven't conducted a formal meta-analysis yet, but the graphs for untrained and trained individuals are clearly different.

In untrained individuals, there is little to gain from training with higher volumes than 10 sets per week, though data are lacking on training volumes over 20 sets per week. Strength development appears to be largely unaffected by training volume at all. While the best-fit trendline is positive, the effect sizes are scattered all over the place and the highest training volumes produced below-average strength gains.



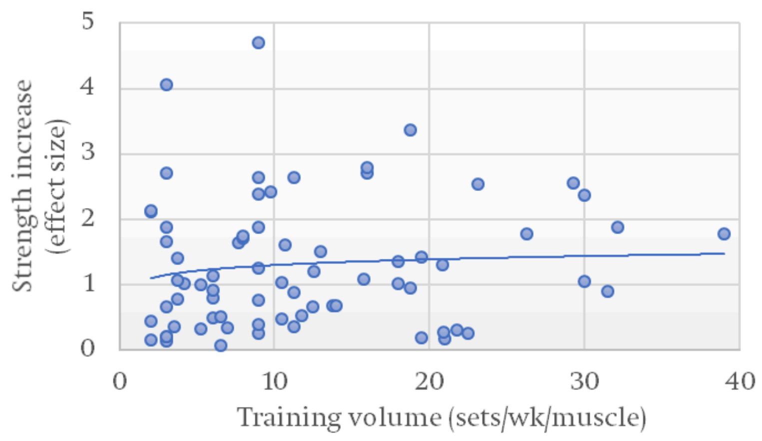
Effect of training volume on strength development in untrained individuals.

Muscle growth does seem to increase but at best 50% on average when going up from just about any training all the way up to 20 sets per week. However, there is no clear dose-response effect above 10 sets per muscle group per week.



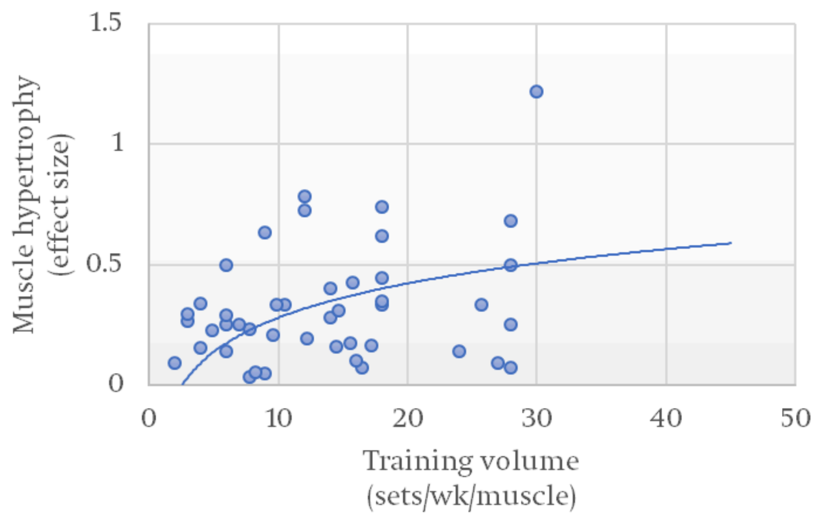
Effect of training volume on muscle growth in untrained individuals.

Whereas untrained individuals don't seem to benefit much from higher volumes than 10 sets per week per muscle, studies on trained individuals paint a different picture, especially for muscle growth. Strength development is again not majorly affected by training volume but does increase from an effect size of about 1 to 1.5 when going from minimal training volumes to 10-20 sets per week.



Effect of training volume on strength development in trained individuals.

Muscle growth in trained individuals shows a clear dose-response curve with diminishing returns, exactly as we'd expect, up to 20 sets per muscle group per week. After that, the trendline is still positive, but the data are scattered wildly around the average.



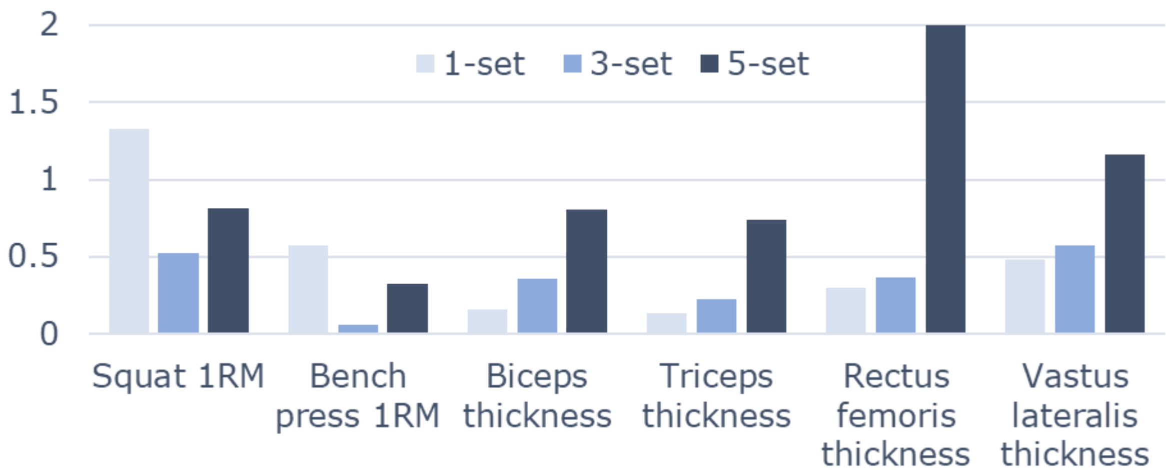
Effect of training volume on muscle growth in trained individuals.

These data align with [a 2022 meta-analysis on the optimal training volume in trained lifters by Baz-Valle et al]. There was a dose-response effect of training volume on muscle growth with significantly greater gains with 12-20 hard sets per week per muscle group than with 1-11 sets. More than 20 hard sets per muscle group per week did not result in significantly more growth in the biceps or quadriceps muscles, but it did in the triceps. To understand the data, we should look at the most relevant higher-volume training studies in detail.

[Radaelli et al. (2015)] had a long duration (6 months), studied a relevant population (military personnel) and compared 3 training volumes. The participants performed 1, 3 or 5 sets per exercise with 2 exercises for the biceps and 3 for the triceps in a 3x per week full-body training program. So for the biceps the set volumes per week were 6, 18 and 30; for the triceps they were 9, 27 and 45. All sets were performed to failure with a rest period of 90–120 seconds in between sets. With the exception of the bench press, the results for all measures showed a more-is-better dose-response all the way up to the super-high volumes, as illustrated below.

Data from Radaelli et al. (2015).

Schoenfeld et al. (2019) employed a similar design with strength-trained men performing 1, 3 or 5 sets per exercise during an 8-week study. This led to a total weekly number of sets per muscle group of 6 and 9 sets for the 1-set group, 18 and 27 sets for the 3-set group and 30 and 45 sets for the 5-set group in the upper and lower limbs, respectively. So training volume was 50% higher for the quads than for the triceps and biceps. All sets were performed to failure with 90 seconds rest in between sets. As illustrated below, there was no effect of training volume on strength development at all, while there was a clear dose-response of training volume with higher volumes resulting in markedly greater muscle growth.



Effect sizes calculated by Menno Henselmans based on Schoenfeld et al. (2018)'s training volume dose-response study.

Brigatto et al. (2022) had strength-trained men perform either 16, 24 or 32 weekly sets to failure for their biceps, triceps and quads for 8 weeks. They rested 1 minute in between sets. They found a relatively clear dose-response effect of training volume on muscle growth and squat strength, though the dose-response was not clear for bench press strength. You can see their results in the tables below: the mean difference (MD) and percentage increases (Δ%) go up with training volume for all comparisons except the 24-set volume for the bench press. The 32-set group had the best results for all outcomes.

Table 4

Before and after 8 weeks of muscle strength measures (mean ± *SD*).*

Variables	Before	After 8 weeks	Δ%	MD (95% CI)	Time *p*	Time × group *p*
$1RM_{BENCH}$ (kg)						
G16	93 ± 20	115 ± 21†	23.6	22.1 (14.2–29.9)	0.001	0.275
G24	103 ± 23	124 ± 23†	20.9	21.5 (16.8–26.2)	0.001	
G32	98 ± 20	126 ± 17†	28.7	28.2 (21.1–35.3)	0.001	
$1RM_{SQUAT}$ (kg)						
G16	105 ± 20	123 ± 19†	16.6	17.5 (13.8–21.2)	0.001	0.038
G24	117 ± 32	138 ± 32†	18.1	21.2 (17.6–24.7)	0.001	
G32	121 ± 27	151 ± 25†‡	25.4	30.7 (18.6–42.8)	0.001	

*G16 = 16 weekly sets per muscle group; G24 = 24 weekly sets per muscle group; G32 = 32 weekly sets per muscle group; $1RM_{BENCH}$ = 1 maximal repetition test in bench press exercise; $1RM_{SQUAT}$ = 1 maximal repetition test in parallel back squat exercise; MD = mean difference; 95% CI = 95% confidence interval.
†Significantly greater than the corresponding preintervention value ($p < 0.05$).
‡Significantly greater than the G16 post–8-week value ($p < 0.05$).

Table 5

Before and after 8 weeks of muscle morphology measures (mean ± *SD*).*

Variables	Before	After 8 weeks	Δ%	MD (95%CI)	Time *p*	Time × group *p*
MT_{BB} (mm)						
G16	38.2 ± 3.9	38.4 ± 3.9†	0.5	0.2 (0.1–0.3)	0.01	
G24	38.2 ± 4.5	38.7 ± 4.6†	1.3	0.5 (0.2–0.8)	0.001	0.206
G32	35.6 ± 3.1	36.7 ± 3.0†	3.1	1.1 (0.8–1.4)	0.001	
MT_{TB} (mm)						
G16	33.9 ± 4.3	34.2 ± 4.3†	0.8	0.2 (0.1–0.4)	0.022	
G24	33.6 ± 4.3	35.0 ± 4.7†	4.0	1.3 (0.5–2.1)	0.001	0.001
G32	35.9 ± 3.8	38.4 ± 4.2†‡	7.0	2.5 (1.9–3.1)	0.001	
MT_{VL} (mm)						
G16	36.2 ± 4.4	36.9 ± 4.0†	2.1	0.7 (0.1–1.3)	0.001	
G24	35.4 ± 5.0	37.4 ± 4.6†	5.6	1.9 (1.2–2.7)	0.001	0.001
G32	37.1 ± 5.1	40.6 ± 5.1†‡	9.4	3.4 (2.9–3.9)	0.001	

*G16 = 16 weekly sets per muscle group; G24 = 24 weekly sets per muscle group; G32 = 32 weekly sets per muscle group; MT_{BB} = muscle thickness of the biceps brachii muscle; MT_{TB} = muscle thickness of the triceps brachii muscle; MT_{VL} = muscle thickness of the vastus lateralis muscle; MD = mean difference; 95% CI = 95% confidence interval.
†Significantly greater than the corresponding preintervention value ($p < 0.05$).
‡Significantly greater than the G16 post–8-week value ($p < 0.05$).

Enes et al. (2023) compared 3 different training volumes in well-trained men (squatting about 3 plates).

1. The 'low' volume group did 22 sets of quad work per week, split evenly over 2 workouts with squats, leg presses and leg extensions.
2. The 'medium' volume group added 4 sets of weekly quad work every 2 weeks, ending up with 42 sets per week just for the quads. The average set volume was around 32 sets per week.

3. The (ultra) high volume group added 6 sets every 2 weeks, ending up with 52 sets per week of quad work. The average set volume was around 38 sets per week.

Total macronutrient intakes did not differ between groups, nor did any other aspect of the programs. The rest intervals were over 2 minutes in between sets and they trained with 2 reps in reserve for their sets, except for the last set, which was taken to failure. After 12 weeks, there was in absolute terms a dose-response effect with higher volumes resulting greater size gains according to both muscle thickness and cross-sectional area, measured over 72 h after the last workout, and 1RM squat strength gains. The sum of muscle thickness increase was 3% for the low volume group, 5% for medium and 9% for high. 1RM squat gains were 9% for the low, 13% for the medium and 19% for the (ultra) high volume groups. Not nearly all comparisons reached statistical significance though.

Based on these studies, it may seem like trained individuals should simply train with as much volume as possible. The more volume, the better the gains?

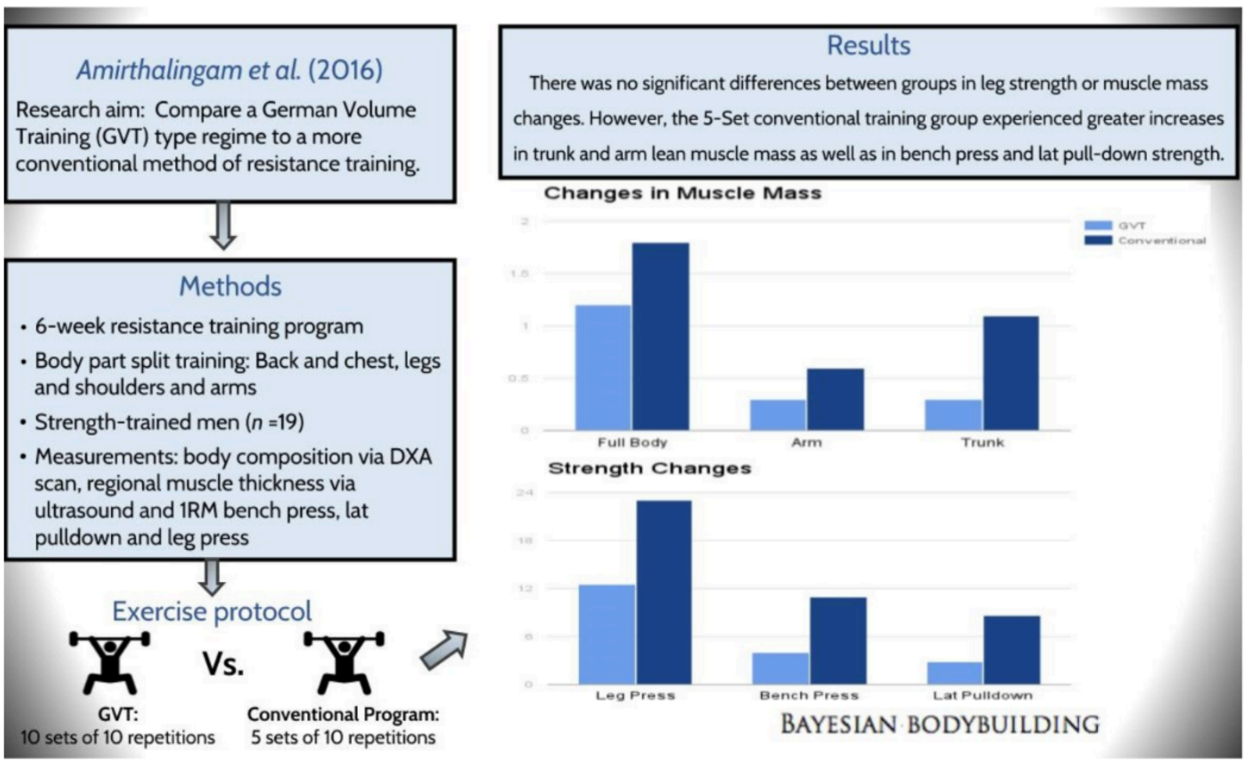
No, some studies find detrimental effects of very high training volumes. For example, Amirthalingam et al. (2016) compared German Volume Training (GVT), a popular bodybuilding split routine, against a lower-volume variant with 5 instead of 10 sets for the primary exercises. Here are the training protocols. The subjects trained 3x per week.

Table 1. Resistance training protocol.

Session 1			Session 2			Session 3		
Exercise	Load	Sets x repetitions	Exercise	Load	Sets x repetitions	Exercise	Load	Sets x repetitions
Flat Bench Press [a]	60% 1RM	10 or 5 x 10	Leg Press [a]	80% 1RM	10 or 5 x 10	Shoulder Press [a]	60% 1RM	10 or 5 x 10
Lat-Pulldown [a]	60% 1RM	10 or 5 x 10	Dumbbell Lunges [a]	70% 1RM	10 or 5 x 10	Upright Row [a]	60% 1RM	10 or 5 x 10
Incline Bench Press	70% 1RM	4 x 10	Leg Extensions	70% 1RM	4 x 10	Tricep Pushdowns	70% 1RM	4 x 10
Seated Row	70% 1RM	4 x 10	Leg Curls	70% 1RM	4 x 10	Bicep Curls	70% 1RM	4 x 10
Crunches	close to RM	3 x 20	Calf Raisers	close to RM	3 x 20	Sit-ups with twist	close to RM	3 x 20

[a]10 and 5 sets respectively for these exercises (10-SET, 5-SET)

And here's an overview of the results.



The higher-volume group gained less arm and trunk muscle, yet for the lower body there were no significant differences between groups. There was a trend ($p < 0.1$) for less muscle growth in the anterior thigh muscle thickness (the quadriceps) in the GVT group though. These findings make sense, because the training volume for the arms, quadriceps and shoulders was extremely high in the 10-set group, since these body parts were semi-unintentionally trained twice per week, a common oversight in split routines that try to target each muscle group only once per week. A similarly common bias in bro bodybuilding routines is that ‘the legs’ are treated as a single muscle group and most exercises for ‘the legs’ primarily target the quadriceps, neglecting the posterior chain (hamstrings, calves and gluteus muscles). Due to the compound exercises targeting the arms, quadriceps and shoulders as well, the total weekly training for the triceps, biceps and quadriceps was well over 20 sets and for the anterior deltoids the training volume was over 30 sets. For novice level trainees, this was evidently excessive.

Based on all the data, novice trainees can likely maximize their gains with around 6-10 sets per muscle group per week, whereas trained individuals generally need 12-20 sets, sometimes more.

Interaction with other program variables

The previous section gave you a rough idea of the optimal training volume based on the averages we see in studies. However, you saw that there’s wide variance in individual study results with some studies finding it’s beneficial to go all the way up to 45 sets a week per muscle group and yet other studies find detrimental effects well before this point. The subjects’ training status is one factor that could explain some of the differences, but other program variables likely also matter.

Rest intervals

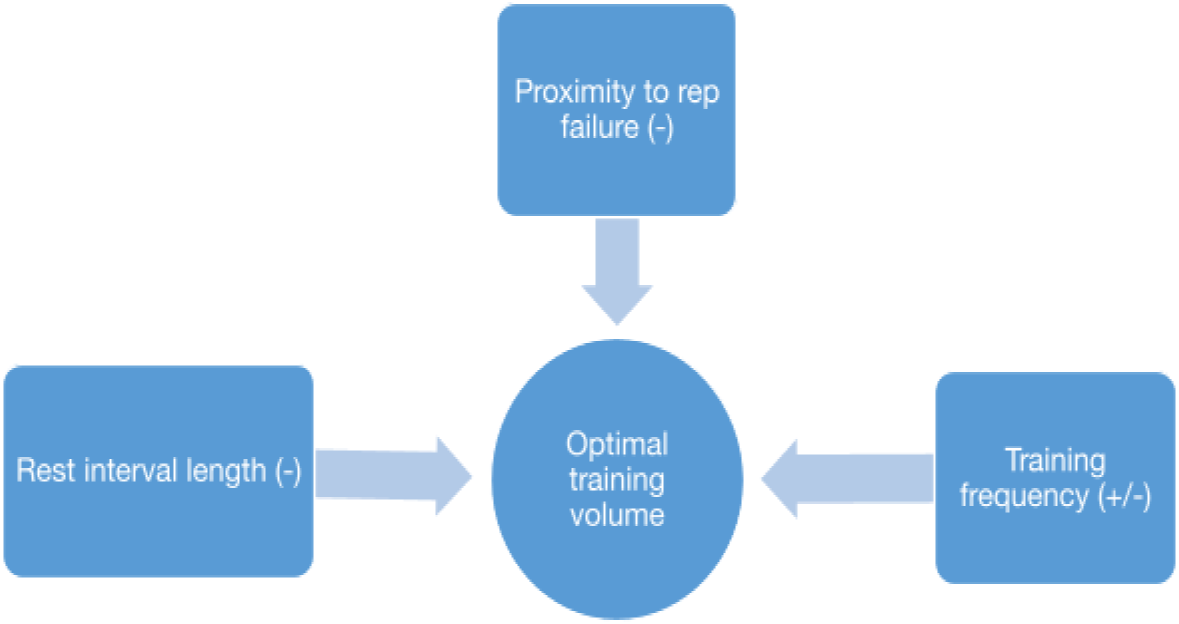
All of the above super-high-volume studies except Enes et al. (2023) employed rest periods in between sets of only 60–120 seconds. This considerably reduces the overall training volume of the session, especially when training to failure, compared to resting 3+ minutes in between sets. So those 32-45 sets may have been equivalent to 16-30 sets with longer rest periods in terms of repetition volume. Rest intervals are discussed in further detail in the module on how to structure your workouts.

Proximity to rep failure

The optimal training volume also interacts with how close to failure you train. Most studies have the subjects supposedly train to failure, but other research finds that volitional failure often does not entrail true rep failure. If you train further away from failure, you'll need more sets to get equivalent results as if you trained closer to failure. Proximity to failure is discussed in more detail in the exercise performance module.

Training frequency

In the section on training frequency below we'll discuss why there may be an upper limit of productive training volume per session. Higher training frequencies can also improve some aspects of recovery and thereby potentially increase the maximum recoverable training volume. However, higher training frequencies also inherently increase training volume. Thus, the effect of training frequency on the optimal training volume is ambiguous.



The optimal training volume depends on the overall structure of the program, including in particular how close to failure you train, how long you rest in between your sets and possibly how often you train each muscle group.

Moreover, the optimal training volume depends not only on the design of the overall training program but also on the recovery capacity of the trainee, akin to the effect of training status.

Recovery capacity

Evidently, training volumes above 20 sets per muscle group per week warrant caution, as at this point research shows the potential for a reduction rather than an improvement in results. To ensure you stay in the optimal training volume range and don’t cross over into the overreaching range, training volume should be based on recovery capacity. People vary considerably in how much volume they can tolerate without getting injured or overreached based on several factors.

Stress and sleep

In the Lifestyle module, you learned that psychological stress can effectively double the time it takes for someone to recover from their workouts. Sleep deprivation can be similarly destructive for someone's ability to sustain high training volumes.

Biological sex and age

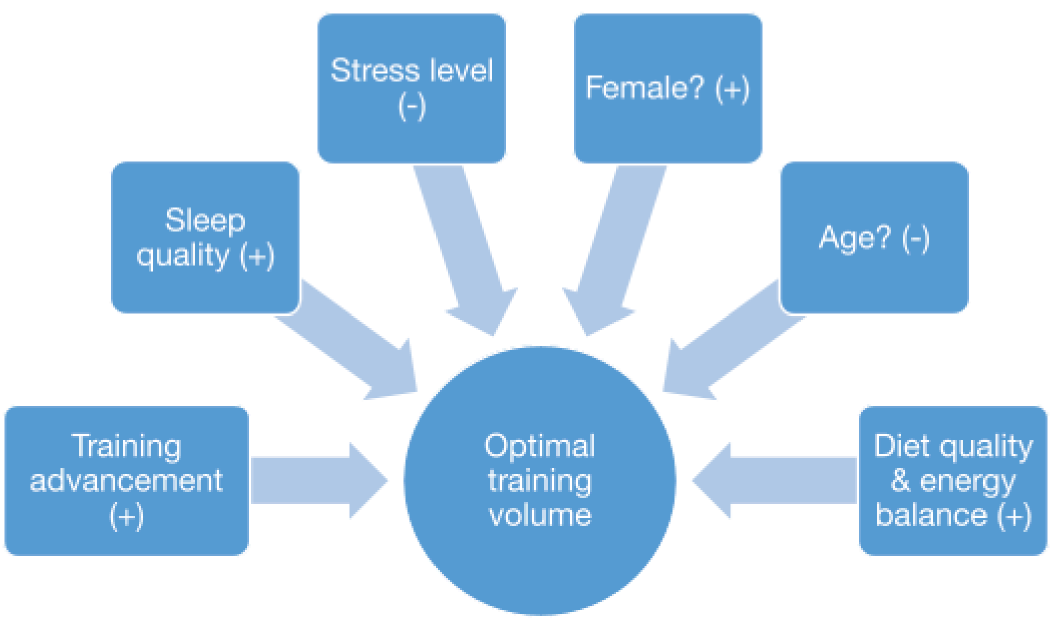
In the modules on sex- and age-specific programming, you'll learn that women can probably tolerate a bit more volume than men and elderly individuals may not tolerate as much volume as younger individuals.

Diet quality and energy balance

Another important factor is diet quality. In the protein module, you learned that a high protein intake makes trainees recover faster from a given workout. Energy balance also affects protein balance, so an energy deficit likely causes a recovery deficit. Research finds that overtraining is far more likely in energy deficit than energy surplus. We don't yet have research on the complex interactions of the optimal training volume and nutritional factors, but we can draw an analogy to the literature on wound healing. Wounds heal more quickly when your diet is more anabolic, in particular if it's high in protein and energy. Analogously, it's likely that the more anabolic someone's diet, the higher the potential for muscle growth and the better someone's recovery capacity. This includes nutrient timing and thereby nutrient partitioning, the inflammatory index, whether sufficient macro- and micronutrients are being consumed, energy balance, food choices, everything. For example, one study found that during Ramadan fasting athletes gain strength **faster** when they reduced their volume by 22% than when they stuck with their previous training volume.

Protein and energy intake are probably the most important factors by far based on their effects on protein balance and wound healing. Thus, in an energy deficit, the total training stress should be reduced. This can be achieved in many ways, but the simplest method by far is to reduce the training volume. In our experience and based on the literature, in particular the Ramadan fasting study, a 20-33% reduction in volume is generally appropriate during a cut compared to during a bulk.

In practice though, while training stress can generally be increased when someone transitions to a bulk, sometimes it's not needed to reduce the training stress when transitioning to a cut. During a prolonged cut, if good progress has been made, it's not uncommon for someone to have become advanced enough to handle the same training volume in an energy deficit.



Determinants of an individual's optimum training volume for maximum muscular development: the better someone's recovery capacity, the more volume they should be able to productively tolerate.

Practical application

Finding someone's individual training volume is clearly complex and dependent on a multitude of factors. To help you get an estimate of someone's optimal training volume, you can use the following calculator. You should think of the output from this calculator as a guideline. The calculator considers only the listed factors, so if there are other factors at play that likely influence someone's volume tolerance, such as performance enhancing drugs or elite genetics, you'll have to account for that manually. The calculator assumes that your program design in terms of proximity to failure, diet set-up, rest intervals and training frequency is in line with the course recommendations. If that's not the case, you'll have to adjust it accordingly. For example, if someone does not train remotely close to failure, they'll probably benefit from a higher volume than the calculator prescribes, whereas if someone's diet and program design are very suboptimal, they may not tolerate as much as the calculator prescribes.

➢ **Training volume calculator**

Now that you have an idea of how to set someone's training volume, we can discuss how to distribute this volume across the week and create a training split. The most fundamental variable that determines how you distribute your volume across the week is your training frequency.

Minimum effective volume

We don't always have time or motivation to get the optimal training volume for progression in. Sometimes we have other preoccupations in life that make us work out less frequently. Unfortunately, "use it or lose it" is true for muscle mass and strength development. If you stop going to the gym, you will slowly lose your gains. It'll be easier to regain your gains after detraining due to muscle memory (see the course module on understanding muscle growth), but to use another saying, an ounce of prevention is worth a pound of cure. So how quickly do you lose muscle and strength if you don't train at all? And what's the minimum amount of training we need to do to maintain our gains or progress?

Detraining: how quickly do you lose your gains?

If you're a novice level trainee, detraining does not occur quickly. People that have been training for only a few months typically lose their gains more slowly than they built them [1, 2, 3, 4, 5]. After weeks or even months off training, most trainees are still much better off than when they started and it only takes a few weeks to get back all their lost muscle. Trained individuals detrain more quickly. For advanced trainees, detraining occurs at a more rapid rate than their typically slow rate of progress. If you've been training very intensely with a high training volume, you're still at virtually no risk of losing any muscle up to a week without training outside of energy deficit, but thereafter you generally start losing your gains gradually. Hortobágyi et al. (1993) found considerable albeit not consistently statistically significant decreases in strength, muscle activity and muscle mass, especially in the type II fibers, after 2 weeks without training in high-level power athletes. Even with light training, detraining tends to set in after 2 weeks. Zaras et al. (2014) observed strength loss after 2 weeks of very submaximal speed work in competitive track-and-field throwers. After about a month off any training, the rate of detraining tends to speed up.

Your exact rate of detraining will be influenced by all the factors that also regulate muscle growth, such as your protein intake, energy balance and sleep quality. One particularly important factor is your activity level. Competitive athletes lose their strength gains much less quickly than sedentary individuals when they stop strength training. In contrast, complete immobilization or bedrest results in extremely rapid detraining, including decreases in muscle protein synthesis. Hospitalized and ill athletes often suffer performance losses within a matter of days. Even relatively effortless daily life movements still activate a large portion of our muscle fibers, especially the type I muscle fibers, and when this 'maintenance volume' is removed, all of those muscle fibers will also start to atrophy.

Minimum effective volume & maintenance

Fortunately, it takes very little training to prevent detraining. There's a big 'maintenance gap' in between the minimum volume needed to maintain your gains and the volume for optimal progress. A single workout per week generally prevents detraining, especially in young novice trainees [2, 3, 4]. Once workout every other week is not enough to prevent detraining in most studies, in line with the finding that it takes about a week before muscle and strength loss set in. A 2020 meta-analysis found that just a single set to failure per week can generally increase muscle strength in novice level lifters. Although this strength development is likely primarily due to neural adaptations rather than increased muscle mass, we can probably assume that training a body part with enough volume for strength development is also enough to at least maintain muscle mass, as muscle loss should reduce strength over time.

Maintenance is probably more difficult for more advanced trainees, the elderly, and lifters in energy deficit, as there's a stronger stimulus for the body to catabolize the 'excess' muscle mass [2]. In general, if it's tougher to build muscle for whatever reason, it's probably also tougher to maintain muscle. Only energy deficit seems to make a big difference though.

Looking at more trained individuals, Ronnestad et al. (2011) found that professional soccer players could also maintain their gains on 1 weekly workout but not a workout every other week. Moreover, multiple studies have reported muscle growth on 3 sets per week per muscle group, sometimes as little as 1 set to failure per week, even in seriously trained lifters [3]. Based on a series of studies, Androulakis-Korakakis et al. (2021) concluded the minimum effective volume for strength development in powerlifters is as low as 3-6 sets per week per powerlift. Again, strength development likely at least entails muscle maintenance. A 2021 review by Iversen et al. similarly concluded that the minimum effective volume for most lifters is around 4 hard sets per week. That's doable in 1 intense full-body workout per week.

Looking at older individuals, Bickel et al. (2011)'s study also had a group of 60-75-year-old trainees doing the same programs as the younger trainees. The older trainees managed to maintain their gains, and even gain a little strength, on a single weekly workout with only a third of their former volume, but they lost some of their gains on a ninth of their original volume. Antunes et al. (2021) found that elderly female strength trainees could not just maintain but continue making slow gains on 3 full-body workouts with just 1 set per exercise, although the gains unsurprisingly tended to be better with 2-3 sets per exercise.

In conclusion, most lifters should be able to maintain muscle mass and strength on a single full-body workout per week. Novice lifters can generally get away with just a single hard set per muscle group, but more advanced lifters will often need to perform multiple sets per muscle group. When performed to momentary muscle failure, this can even stimulate muscle growth up to a certain level, but the minimum effective volume to make long-term progress for advanced lifters is likely at least 4 sets per week. To make such low training volumes effective, very high effort per set is necessary, generally involving training to muscle failure. The exact minimum effective volume is individual just like the optimum training volume. Certainly not everyone will be able to maximize their muscle growth on low-volume training. ‘Hardgainers’ or ‘non-responders’ to training have been found to require higher training volumes to make progress than the average trainee. You’ll learn quickly enough what your minimum effective volume is, at least for strength development, as you can simply measure whether you’re progressing in strength or not. If you’re not gaining any strength on a low training volume and your overall program design is sound, you probably need to increase your training volume. If you’re making steady progress, you can see if you can continue making good progress on less volume to find your minimum effective volume. Beware though that strength development does not guarantee muscle growth, because it’s very possible to gain strength without size from neural adaptations.

Training frequency

Training frequency can be defined in 3 ways and, as with the discussion of any concept, it's important to agree on definitions to understand the topic.

1. Total training frequency is the number of times per week you go to the gym. If you train on Mondays, Wednesdays and Fridays, your total training frequency is 3.
2. Frequency per exercise is the number of times per week you perform an exercise. If you're on an upper/lower body split with a total frequency of 4 and both your lower body days have squats, your squat frequency is 2.
3. The most relevant definition for muscle growth is the training frequency per muscle group. Your muscles don't care how often you're in the gym or what your training split is. They only react to how often they experience high mechanical tension.

In the early days of natural bodybuilding, almost all bodybuilders did full-body training. However, modern bodybuilders typically train a muscle just once a week. This way you get a huge pump during the workout and a lot of soreness afterwards. But as you've learned, a big pump and sore muscles, or their rationalized variants, metabolic stress and muscle damage, do not equate to muscle growth. And it would be coincidental if the time-course of muscle growth happened to coincide exactly with what we define as a week in the Gregorian calendar.

Nevertheless, most studies find no significant effects of training a muscle more than once a week, given the same total training volume [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16]. A 2019 meta-analysis by Schoenfeld et al. confirms that on average, volume-equated studies find similar muscle growth regardless of training frequency, and a 2021 meta-analysis by Cuthbert et al. finds training frequency also does not impact strength development significantly, independent of training volume. Similarly, a 2024 meta-analysis on full-body vs split routine training found that strength and size gains did not significantly differ between the programs on a set-equated basis.

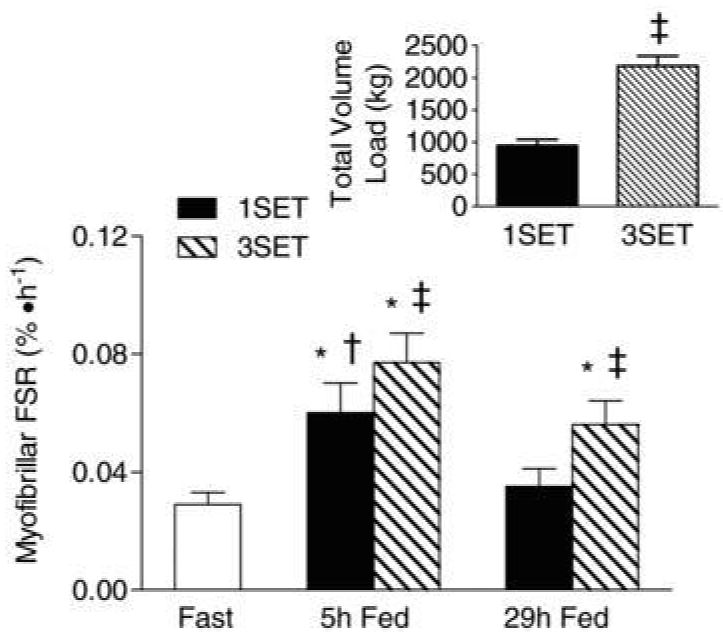
However, most of these studies have one key design feature in common: they're in untrained participants. In untrained subjects, the research is overall clear that there are no benefits to training a muscle more than once per week, given the same total training volume. However, there are no studies finding negative effects of higher training frequencies and there are 4 studies that find significant benefits of training a muscle more often even without an increase in weekly set volume:

1. Ochi et al. (2018) found training a muscle 3 times per week resulted in greater strength gains though not muscle growth than training a muscle once a week.
2. Pina et al. (2020) found greater fat loss with similar strength development and muscle growth when training 3x per week instead of 2x per week.
3. Yoshida et al. (2022) found greater strength development when performing 1 set of 6 maximal eccentric contractions 5 times per week than when performing 5 such sets once a week.
4. Cardoso et al. (2024) found greater strength gains with a 3x/week full-body split than the same volume performed as 3 alternating upper-lower workouts. Muscle growth didn't differ between groups.

We've seen that the time-course of muscle protein synthesis decreases in trained individuals, less muscle is built per workout and the recovery rate increases. Based on this, trained individuals may require higher training frequencies to keep building muscle around the clock. If MPS only remains elevated for 24 hours after a workout, it logically follows that you need to train a muscle group every single day for maximum muscle growth. However, there are 2 reasons why this may not be the case.

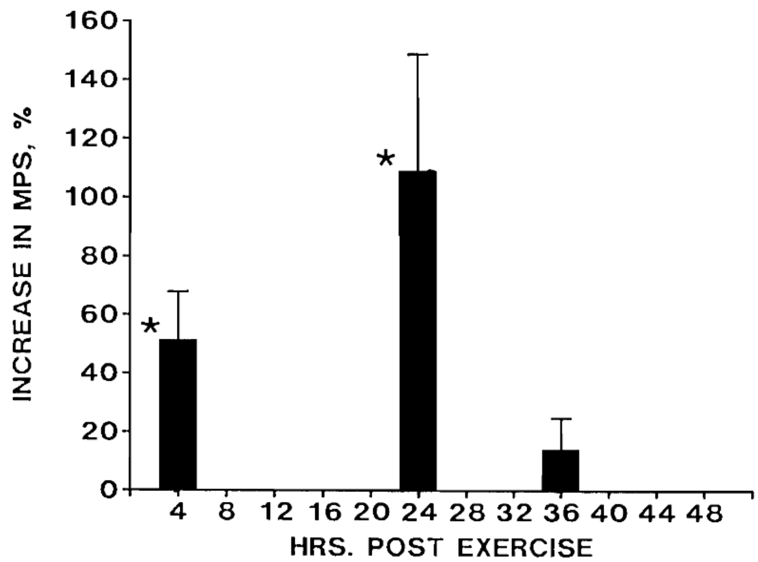
MPS vs. training frequency

For one, higher training volumes can elongate the anabolic window. Burd et al. (2010) compared the anabolic window length of 1 vs. 3 sets of leg extensions in recreationally trained men. Tripling the training volume significantly increased protein synthesis at 5- and 29-hours post-workout: it basically shifted the whole anabolic window MPS-time curve upward by around a third (see figure below).



If we extrapolate these results linearly over time, this could postpone the anabolic window from about a day to about two days, quite plausibly longer with training volumes over 4 sets per muscle group per session.

However, other research suggests more modest effects of training volume on MPS duration. In recreational bodybuilders, biceps MPS levels had returned to within 14% of resting levels within 36 hours after 12 sets of biceps curls to failure: see the figure below.



The second reason the MPS literature may not tell the whole story of the ideal training frequency is that most research looks at mixed MPS. For nutrient timing, this is all that's important, as we want to fuel all MPS. However, for training frequency, we're not concerned with peak total MPS but the total duration of myofibrillar MPS. As long as myo-MPS is elevated, a muscle is still growing from the previous workout. Since myo-MPS is a part of mixed (total) MPS, you would expect that a return of mixed MPS to baseline logically implies that myo-MPS has also returned to baseline. However, our measurement methods are apparently not refined enough for this, as some research impossibly finds that myo-MPS remains elevated longer than mixed MPS.

Training frequency studies

So we cannot assume that the anabolic window length is perfectly reflective of the optimal training frequency. With that in mind, let's look at the training frequency literature in people who actually lift. We've summarized the research in the link below. Unless mentioned otherwise, these studies are all randomized controlled trials comparing different weekly training frequencies per muscle group of otherwise identical, work- or set-equated programs. Example: one group performs a single full-body workout on Monday and the other group splits up that exact same workout across 3 workouts on Mon-Wed-Fri.

➢ Research overview

Training frequency studies in trained participants

Overall, it's clear that training frequency isn't nearly as important as training volume. Given the same total work, most studies find no significant difference in strength development or muscle growth.

However, several volume-controlled studies do find significant benefits and even more find positive trends. In contrast, there is only a single controlled study, Saric et al. (2018), in which the lower frequency group achieved significantly better results than the higher frequency group, and it was only on one out of multiple measures in a 6-week study with all other measures showing no between-group difference. The overall trend in the literature suggests there are benefits to higher training frequencies but they are obscured by low statistical power.

In several studies, the low statistical power is evident. For example, McLester et al. (2000) studied barely intermediate level trainees performing a very low volume of training in either 1 or divided over 3 full-body workouts per week. The only between-group comparison that reached statistical significance was the leg press (22% vs. 46%) in favor of the higher training frequency, but the trend throughout all time-points and for all measurements – even diastolic blood pressure – was clear. The researchers called it a 'definite trend'. Lower body strength increased by 23.5% and 37.4% in favor of the 3-day group. Upper body strength increased by 20.2% and

32.4% in favor of the 3-day group. Total lean body mass increased by 1% and 8% in favor of the 3-day group. Statistical power was almost certainly too low to reach statistical significance for multiple reasons.

- There was no diet control.
- The volume was extremely low: 3 sets per week.
- Calipers were used to estimate body composition.
- There was large variance in the samples in gender and training experience.

A better controlled study would most likely have found these effects to be statistically significant in favor of the higher training frequency.

Normally meta-analyses provide a great solution to detect trends in the overall literature that may not reach statistical significance in individual studies, but in this case even meta-analyses are not fully consistent. An unofficial meta-analysis by Greg Nuckols, arguably with the best methodological design, found significantly greater strength development and muscle growth with each additional training day per muscle group per week even when the total set volume per muscle group was equated between groups [2]. However, meta-analyses by Ralston et al. (2018), Grgic et al. (2018) and Cuthbert et al. (2021) found no significant difference in strength development between low and high training frequencies when training volume was equated and a 2019 meta-analysis by Schoenfeld et al. found no significant difference in muscle growth on a volume-equated basis, though the latter analyses had several considerable design limitations with how they defined training volume and analyzed the data, leading to confounding of other between-study differences than just training frequency. When you lump many different studies together and only look at the average effect sizes per training frequency, your analysis is confounded by between-study differences. For example, studies employing higher training frequencies tend to be performed on more advanced trainees than the lower training frequency studies. This means you'll confound the likely positive effect of training frequency on strength with the likely negative effect of training age on strength, which means you may get no difference on average even though there is a positive effect of training frequency.

Most importantly, most studies are volume-equated. This is in practice never the case, as training frequency affects training volume.

Training frequency vs. training volume

In a scientific study, it is relatively easy to design 2 work-equated programs. However, in practice when people train close to failure, increasing a muscle's training frequency almost invariably increases its total work volume. When you split up a given number of exercises or sets across more sessions, you'll perform more work because you're less fatigued on average. Let's say you take a typical Monday chest day with 5 pec exercises performed for 3 sets each. The last exercise is the weighted push-up. Now you take those 5 exercises and you spread them out across the week, which means on Saturday you do only 3 sets of weighted push-ups for your pecs. In which condition can you perform more reps with a given weight: after 12 sets of chest work on Monday or when you're still fresh and fruity on Saturday?

Obviously, your performance is better when you perform an exercise fresh instead of when you're already exhausted. Just after your warm-up, your nervous system is still fresh and metabolic waste has yet to accumulate in your blood. Your body is in a perfect state to adapt to anything you throw at it. As rigorous training commences, muscle fibers and connective tissue tear, energy substrates deplete and metabolic waste products accumulate in the blood. The breakdown of AMP and BCAAs causes ammonia accumulation in your muscles and brain, causing some degree of brain toxicity and various neuromuscular disturbances. The result is neuromuscular fatigue.

This fatigued state is not conducive to your workout performance. Hartman et al. (2007) found that when nationally competitive weightlifters split their training program over 2 daily workouts rather than one, they experienced double the increase in muscle activation levels (EMG +20.3% vs. +9.1%) during the program.

Greater performance in turn increases training volume tonnage, which means more mechanical tension on the muscle, which can lead to more muscle growth. Neves et al. (2022) illustrated this well. The researchers compared the effect of training a muscle 1x vs. 3x per week for strength and muscle growth using a within-subject design. This is more robust than the typical between-individuals design, as you control for each person's individual genetics, diet and lifestyle. The trainees performed one-legged leg presses. One leg did 9 sets once a week. The other leg did 3 sets 3x per week. A second group did the same program but equalized total training volume work (sets x reps x weight) between frequencies. Since you can normally perform considerably more work with higher training frequencies due to being less fatigued, the 3x per week group had to hold back to perform only the same volume as the 1x per week group. When equating total training tonnage between groups, there were no meaningful differences between the training frequencies, as expected based on prior research. In contrast, the leg trained 3x per week without holding back achieved 2-2.7x more muscle growth than the legs being trained 1x per week group (4.1% vs. 1.5% & 2.1% increases in quad CSA). In other words, it seems the higher training frequency more than doubled their size gains. Leg press 1RM strength increased 25% in the 3x leg compared to 16% & 19% in the legs being trained once per week. None of these differences were statistically significant, but this was likely a problem of statistical power with only 12 lifters per group, trained individuals and a 9-week study. The authors therefore performed an effect size analysis, which showed there was an effect in favor of the higher training frequency when not equating total tonnage. The confidence intervals of the between-group effect sizes for both strength and size did not cross zero in the comparison not equating total work, indicating it was very likely that the difference was real. Put simply, the data showed training a muscle 3x per week can in practice improve strength development and muscle growth compared to traditional bro splits that train each muscle only 1x per week. The benefits are the result of the greater total work capacity.

The effect of fatigue on exercise performance gets worse in stronger individuals as. Stronger individuals have poorer work capacity than weaker individuals: they tend to lose more reps across sets due to fatigue than weaker individuals. Therefore, stronger trainees experience strong diminishing returns to adding sets to exercises in the same workout. This is another reason to implement higher training frequencies in stronger individuals: you can achieve more reps in a given number of sets. So you get higher performance and better time efficiency.

Some research has also found that higher frequency training reduces perceived exertion during the workouts [2, 3]. Splitting up your workouts into more frequent, shorter sessions allows you to spend more time in a fresh rather than a fatigued state, as mental fatigue accumulates during workouts.

As long as you can recover from it, a greater training volume should mean more mechanical tension on your muscle fibers and consequently more growth over time. This may be the reason Greg Nuckols's meta-analyses found greater strength and muscle gains, as he equated total set volume, instead of total work.

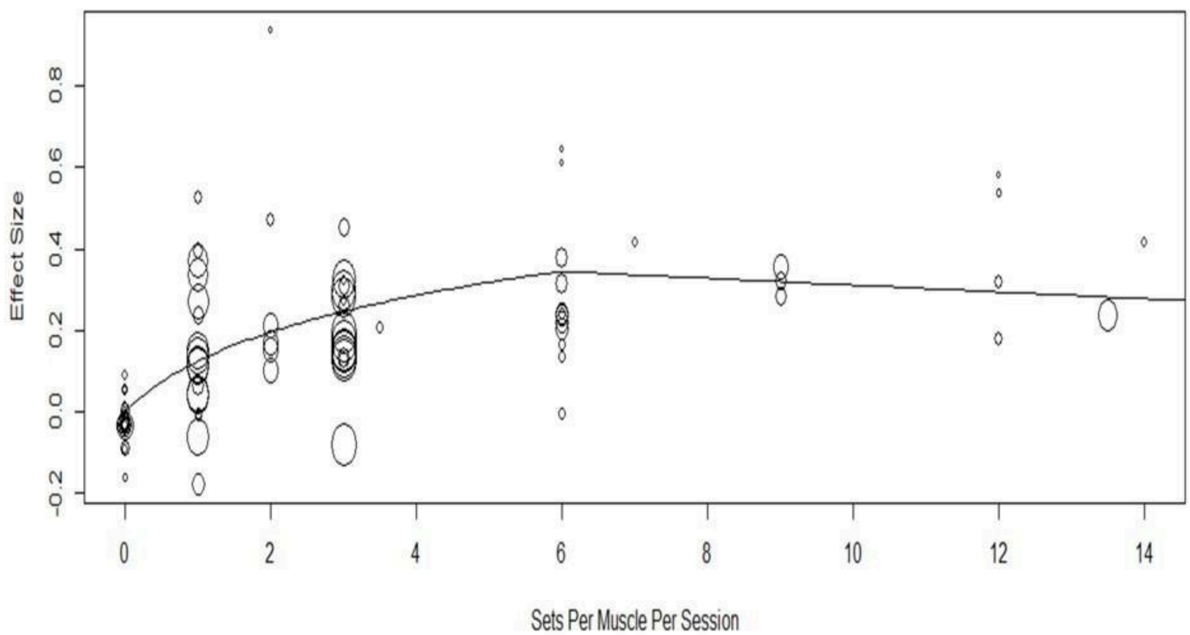
Maximum volume per session

Training frequency and volume may interact not only because splitting your sets across multiple sessions results in higher repetition performance, but higher training frequencies may also allow for higher productive training volumes. If we look at all studies so far that found detrimental effects of higher training volumes compared to lower ones, they did not have absurdly high training volumes but rather a high volume per training session. Programs with more than ~10 sets per muscle group per workout tend to perform poorly.

- Zaroni et al. (2018) found training a muscle 5x per week with 3 sets (a full-body program) resulted in significantly more muscle growth than training a muscle 1x or 2x per week with ~15 sets (a bodybuilding split).
- Amirthalingam et al.'s 2017 German Volume Training study showed better gains in strength and size with 5 instead of 10 sets of their primary exercise per workout. The total set volume per workout was around 9 in the medium volume group compared to 14 in the high-volume group.
- Heaselgrave et al. (2019) found a trend for an optimal training volume of 18 sets per week for the biceps: groups training with 9 and 27 sets achieved worse overall strength and muscle development. The medium- and high-volume groups trained their biceps twice per week, so the high-volume group performed 13-14 sets per workout for the biceps compared to 9 sets for the medium group.

Total volume was not that extreme in any of these studies, no more than 30 sets per muscle per week. In contrast, Radaelli et al. (2015) and Schoenfeld et al. (2019) both found overall greater muscle with 45 compared to 30 sets per muscle per week, which in turn led to greater overall muscle growth than doing 15 sets per muscle. The difference with these studies is that they trained each muscle 3x per week, so the 30-set groups were still 'only' doing 10 sets per muscle per workout.

An unpublished meta-analysis by James Krieger in Weightology, for which alumni of this course get a discount, found direct support for a ceiling effect of set volume per workout on muscle growth. Higher training volumes per workout did not result in more muscle hypertrophy. The plateau already occurred around 6 sets per workout: see the graph below.



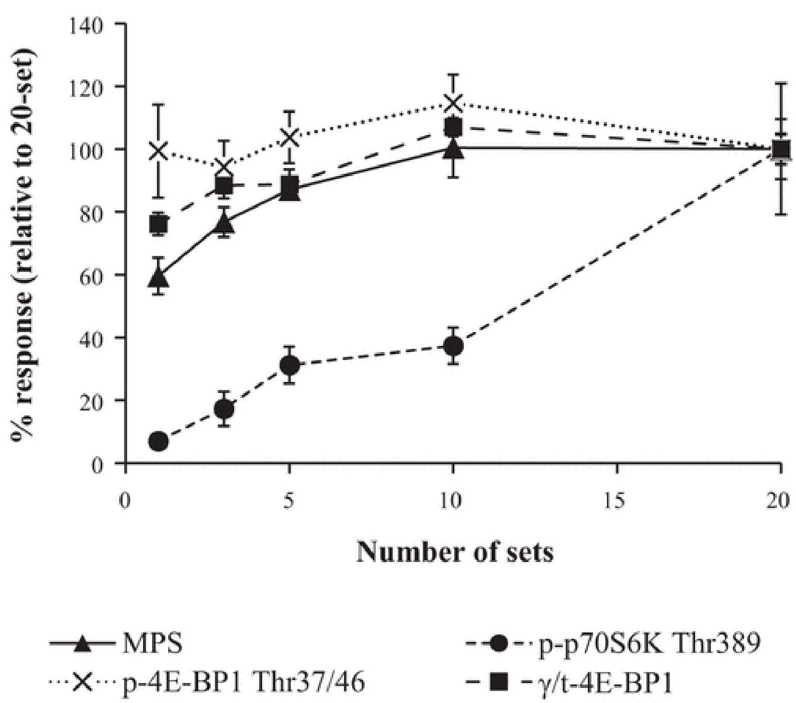
An unpublished meta-regression by James Krieger showed the dose-response effect size of muscle growth plateaus at 6 sets per training session. [Source]

It makes sense that you can only stimulate so much muscle growth in one workout. The body's adaptive capacity is limited. Evolutionarily speaking, it also wouldn't make sense for the body to morph into The Hulk after a single day of extreme manual labor. Adaptations are only desirable against stresses that repeat over time.

There's also a limit to the amount of quality volume you can do in a session. [The accumulation of neuromuscular fatigue and muscle damage can reduce performance, muscle activation and mechanical tension further and further with each extra set]. Not to mention mental fatigue and dwindling training motivation.

Excessive muscle damage may result in negative protein balance as you only further increase muscle protein breakdown levels without stimulating more muscle growth. We know muscle damage causes increased protein breakdown. While it can also cause increased muscle protein synthesis, at some point the balance likely becomes negative.

As a result, after doing about 10 sets you may not be able to increase muscle protein synthesis (MPS) further anymore. Human data to characterize the precise dose-response relation between set training volume and MPS are scarce, but they at least support diminishing returns. While there are clear MPS increases when going from 1 to 3 sets per workout, and from 6 to 8 sets, when increasing the training stress beyond 8 sets per workout, there's only a small further increase that's not related to muscle growth, suggesting it's cancelled out by protein breakdown from excessive muscle damage. In rats, we have good research showing anabolic signaling and MPS plateau around the 10–set mark: see the figure below.



Source

In conclusion, the research suggest that productive training volume is limited to 6-10 sets per muscle group per workout. The exact optimal volume likely depends on the specifics of the training program, in particular how close to failure you're training, the rest intervals and individual factors like genetics.

Practical application on training frequency

Training frequency is a matter of program fine-tuning that mostly matters because it affects training volume. Total volume is most important. In practice you design a program with a certain number of sets in mind rather than a certain amount of total work and spreading your sets across more sessions per week, thereby increasing the training frequency per muscle group, which leads to a higher total repetition volume. You would thus expect higher frequencies to benefit size and strength gains in practice. While most studies find training frequency does not significantly affect our gains independent of training volume, multiple studies favor higher frequencies and essentially none favor lower frequencies.

Benefits of higher training frequencies are found mostly in more advanced trainees on higher training volumes. In untrained individuals, there are only a few studies finding significant benefits of training a muscle more than once per week and none found improved muscle growth. In trained individuals, there are several studies finding significant benefits of training a muscle more than twice per week. The highest beneficial training frequencies are all found in advanced lifters on high training volumes. This trend aligns with the theory that as you get more advanced, your anabolic window shortens, there is less protein breakdown during training and you become more resistant to muscle damage and neuromuscular fatigue. Trained muscles may therefore benefit from a higher total training load and frequency of exercise

Strength-trained individuals should thus generally exercise each muscle group at least twice per week: there's potential upside without any downside. For maximum muscle growth, we recommend you program at least 1 weekly workout per week per muscle group for every 6 sets you do for that muscle group, as there appears to be a ceiling effect for muscle growth with higher volumes per training session. For example, you should train a muscle at least 3x per week when your training volume exceeds 12 sets per muscle group ($2 \times 6 = 12$). Advanced trainees pushing their training volume to their limits may benefit from training each muscle as much as daily or even twice daily.

Another large practical benefit of higher training frequencies and full-body workouts is that they can save you a ton of time, because they allow you to train non-overlapping muscle groups while other muscles are resting. We'll cover this in greater detail in the module on exercise ordering.

All in all, since there are potential benefits and no downsides to training muscles more frequently, you can err on the side of higher training frequencies. In fact, a perfectly defensible interpretation of the literature is to simply always perform full-body workouts. If this sounds extreme to you, remember that this is how almost all bodybuilders and strength athletes trained up to the 60s. Split routines only became mainstream in the 50s. And for most athletes, full-body workouts remain the norm. Bodybuilders are the outliers. That said, split routines can clearly be just as effective as full-body routines, so if someone strongly prefers a conventional bro body part split, upper/lower or push/pull/legs, those can be perfectly viable, provided you get enough total volume in.

What about recovery?

A common concern of high-frequency training is that there is no time for recovery. However, this is fundamentally misguided reasoning, as for recovery just like for muscle growth, total volume, not training frequency, is key.

While there are many studies finding it takes several days to recover from a workout, the vast majority of these studies are practically irrelevant, because they subject people to a novel training stimulus. Muscle damage and soreness are very high after you perform a workout your muscles are not accustomed to. As you perform the workout more often, however, the repeated bout effect occurs.

The repeated bout effect

Repeated what? The repeated bout effect is the phenomenon that trainees develop far less muscle damage when they repeat a workout ('exercise bout') compared to the first time they performed that workout, even if the weights they can lift are now higher. Training causes your connective tissue and your muscle fibers to adapt and become stronger. Basically, what doesn't kill a muscle makes it stronger. Moreover, muscles also seem to become stronger as weaker fibers die off ('fiber necrosis', possibly followed by complete regeneration) and only the strongest cells survive over time. This is why you stop being so sore from most training programs over time.

A pleasant exception to the aforementioned artificial protocols comes from Raastad & Hallén (2000). They studied the recovery time course of a hard but realistic workout in competitive powerlifters and strength athletes. The workout consisted of 3 maximal sets of 3 for both the squat and the front squat with a 6-minute rest interval followed by 3 maximal sets of 6 in the leg extension with a 4-minute rest interval. Recovery was assessed using jump height, leg extension torque and electrical stimulation.

The conclusion: “All performance measures showed the same pattern of recovery after the 100% protocol. There was a decrease in performance of 12 ± 22% post-exercise. Recovery was biphasic, with rapid recovery occurring during the first 11 h, followed by a leveling off or a second drop in performance until the next morning, 22 h after exercise. All variables returned to baseline levels 33 h after exercise.”

So that’s full recovery within 33 hours after 9 all-out, high-intensity sets.

Now, the question remains if your muscles only become more resistant to damage or if they also actually recover faster. If muscles only become more resistant to damage without a change in recovery capacity, then more developed muscles may only need to be trained with a higher training volume without any need for an increased training frequency.

Recovery capacity

The answer seems to be that more developed muscles are not only more resistant to damage, they also recover faster. There are 2 primary mechanisms by which strength trained muscles can have a greater regenerative potential.

1. Larger muscles have more satellite cells and show greater satellite cell and other myogenic cell activity. (If you don’t know why satellite cells increase recovery potential, revisit the course topic on adaptations to strength training and how muscle grows.)
2. Strength training results in angiogenesis, the formation of new blood vessels. These new blood vessels increase blood flow to your muscles, allowing faster delivery of nutrients and removal of waste products. The result is an increased

ability of your skeletal muscles to remodel themselves after being damaged during exercise, i.e. the muscles recover faster.

Recovery time

The Norwegian study is not the only study showing trained lifters can recover within a few days at most from even high-volume training sessions. Several other studies on recovery from practical strength training workouts in trained individuals support that recovery occurs much quicker than many people think.

- Highly trained men can recover their strength from a full-body workout with more than 4 sets per muscle group within 24 hours, though soreness can take 48 hours to dissipate.
- Elite rugby players recover their isometric strength within 48 hours after 5 sets of near-maximal sets of back squats at 85% of 1RM with 5-minute rest between sets, though power was still compromised at 48 h, which may be relevant for athletes.
- Most strength-trained men recover their performance on the bench press after a killer *12 sets to failure* within 48–72 hours or within 48 hours after 4 sets to failure.

Is recovery even essential?

It may also not be necessary to allow full recovery of a muscle before you train it again in the first place. Performing a program on 3 consecutive days of the week (like Mon-Tue-Wed) is just as effective as spreading the sessions out across the week [2]. This suggests your muscles retain their stimulus to grow even if the growth process is interrupted by another workout. However, in practice it is generally beneficial to spread your set volume out across the week, because you should achieve a higher total volume load due to training in a less fatigued state.

The effect of training frequency on recovery capacity.

Moreover, there's good reason to think higher training frequencies **improve** recovery capacity, given the same total set volume. Bartolomei et al. (2022) found that well-trained lifters recovered faster after 8 sets of maximum-effort bench pressing when splitting up the workout into 2 workouts of 4 sets instead of performing all 8 sets in 1 workout. In the 48 hours after the workout, bench press throw power returned to baseline faster and pec swelling subsided more quickly in the bi-daily group. A similar trend was noted for isometric bench press strength, though it did not reach statistical significance. Moreover, they could perform the 8 sets of 10 at an over 10% higher average training intensity (roughly 60% vs. 50% of 1RM), so they recovered faster while also doing about 10% more work.

It seems that the stimulus-to-fatigue ratio of a workout deteriorates across sets, possibly due to impaired neuromuscular efficiency resulting in higher muscle damage when continuing to train in a fatigued state.

Another group of researchers, Raastad et al. (2003), studied intermediate male trainees training either 4x per week with a typical upper-lower split (5 exercises, 3–4 maximal sets each per session) or every day for 2 weeks. Before and after the program, recovery capacity was assessed. The daily training group significantly increased their lower body training volume and started training their quads with 3 maximal sets of 2 exercises, i.e. 6 heavy sets every day (42 sets per week!). This resulted in a significantly greater strength gain in the leg press of 12% in the daily training group compared to 5% in the upper-lower split group. Squats increased by 19% vs. 4% in favor of the daily training group. These are very nice extra gains in the high-frequency group, but are they sustainable for more than 2 weeks?

The recovery test workout consisted of 3 sets of 6 for squats, front squats and leg extensions with their 6RM and a long rest interval to allow for complete recovery between sets (8 min. for the squats; 3 min. for the leg extensions). So that's 9 sets for the quads with heavy loads taken one rep to failure. Recovery measurements indicated the daily training significantly improved resistance to fatigue to the point that leg extension strength recovered within 22 hours after the test session. To quote the researchers, "In conclusion, 2 weeks of heavy training reduced acute neuromuscular fatigue after a test workout. As a result, recovery was complete 22 h after the workout performed after the heavy training period but not after the workout performed before the heavy training period. This faster recovery may explain why daily bouts of leg extensor strength exercise were well tolerated by most subjects."

In conclusion, in contrast to popular belief, higher-frequency training seems to improve recovery capacity for a given total weekly training set volume. Note that simply adding workouts and thereby majorly increasing your total training volume may not improve recovery capacity, as the additional volume will likely take a toll on your recovery capacity.

There are a few possible mechanisms by which higher training frequencies can improve recovery capacity.

1. Reduced muscle damage

In Bartolomei et al.'s study, muscle soreness ratings did not differ between the groups with different training frequencies, yet other research finds spreading your training volume for a muscle out across the week can reduce muscle soreness without reducing muscle growth [2]. Together, these findings suggest splitting up your workouts up into a higher training frequency for that muscle may reduce muscle damage levels. Muscle damages prolongs the anabolic window by upregulating protein breakdown, which means it takes longer before a muscle finishes its net protein synthesis after a workout. So muscle damage is generally undesirable and suffering less of it should allow for faster recovery and a higher total volume tolerance.

2. Active recovery

Plus, a higher training frequency is effectively a form of active recovery. More training equals more blood flow and a greater rate of tissue turn-over. Abaïdia et al. (2017) found that an upper body training session improved the recovery of force production in the hamstrings after they were damaged from their workout the day before.

3. Better hormonal health

Higher frequency training also increases testosterone production and improves the testosterone-to-cortisol (TC) ratio, a measure of overtraining [2, 3] in several studies. The only exception is Häkkinen & Pakarinen (1991), in which training twice a day did not affect the T/C ratio and interestingly decreased it during the deload week. However, isometric maximal force production, a significant correlate of muscle growth, increased to a greater extent in the twice-daily training phase compared to the daily training phase in this study, so evidently the hormonal change was not detrimental. It's plausible that the twice-daily group could train harder due to training in a less fatigued state (despite with the same intended volume) and thereby caused greater hormonal disruptions.

4. Better sleep quality

If by splitting up your workouts you end up training on more days of the week, as opposed to just spreading out your volume more over your existing workouts, you may also benefit from better recovery by virtue of better sleep quality. Strength training significantly improves sleep quality. Even high-intensity training close before bedtime generally doesn't adversely affect sleep quality, though many people think and subjectively report that it does. Given the major importance of sleep quality for recovery (see lifestyle course module), splitting up your program into more workouts may improve recovery capacity. Increasing the frequency per muscle group but not total training frequency probably won't benefit your sleep though.

What about injury risk during high-frequency training?

While higher total training frequencies and higher frequencies per muscle group may improve neuromuscular recovery, there is a concern with increasing the frequency per exercise. Performing a certain exercise more than twice per week may increase the risk of overuse injuries for connective tissues, notably your tendons and ligaments. Anecdotally, most people do not tolerate high-volume training of injury-sensitive exercises such as the 3 powerlifts (squat, bench press and deadlift) more than 3x per week. Powerlifters have a much higher injury rate than bodybuilders and most injuries occur during the powerlifts, yet powerlifters that train with higher *total* training frequencies seem to have *lower* injury rates. An unofficial analysis by Andrew Patton (2017) of 1900 powerlifters also found no effect of training frequency on injury rates. It thus appears that training frequency per se is not the issue but overuse, whether by volume or excessive frequency per exercise, is the culprit.

For the strength development of specific exercises, which is the goal of Powerlifting competitions, higher frequencies may be desirable for maximum strength gains. When the primary goal is muscle growth, however, it is generally advisable to restrict the frequency per exercise to twice a week. Further increases in training frequency per muscle group are best achieved by incorporating more different exercises rather than performing the same exercise more often.

Exercise variety will be discussed in greater detail in the course module on exercise selection.

In summary, higher training frequencies generally improve our ability to recover from a given number of weekly sets for a muscle group, often even while allowing us to train with a higher total training tonnage. Injury risk does not seem to be affected by training frequency, independent of training volume. Overall, higher training frequencies are an effective method to improve the stimulus-to-fatigue ratio of high-volume training programs.

Creating a training split

When you've determined your training frequency in all 3 ways – how often you work out, how often you train each muscle and how often you perform each exercise – this largely determines your training split. Your training split is a categorization of how you split all your training across the week (or whatever other unit of time you prefer to use). If you have 2 different workouts that you alternate between, we can call that a 2-split. If you have a different workout for each day of the week, we can call that a 7-split. So what's the best training split?

The most popular training split by far up until the 1950s was full-body training with 1 to 3 different full-body workouts that somebody alternated through repeatedly. Most classic training programs by Eugen Sandow, Reg Park, Bob Hoffman and the natural bodybuilding titans of old were full-body training programs. Body part splits were popularized only in the 1950s by Joe and Ben Weider. The Weider brothers started by popularizing upper/lower body training splits for more advanced lifters. Later they popularized what we now call bro splits, programs in which every muscle group or limited set of muscle groups receives its own day: arm day, leg day, etc. Bro splits became popular at the same time as androgenic anabolic steroids (AAS) and were heavily popularized by the Weider empire and Arnold Schwarzenegger, making it seem like the bro splits were responsible for churning out more muscular individuals than ever before. Since then, bro splits have been a mainstay in modern bodybuilding.

However, as you learned, modern sciences have not supported the superiority of bro splits. If anything, they have vindicated the knowledge of the natural bodybuilders of old. Most studies find that higher training frequencies are as effective as or more effective than lower training frequencies, so it's hard to go wrong with full-body training. As we'll discuss in the course module on how to set up individual training sessions, full-body training is also generally ideal from a time-efficiency point of view, as it more easily allows the use of combo sets than body part splits.

More importantly, your training split should be determined by the optimization of your training frequency and training volume, not the other way around. Many lifters uneducated in exercise science start with their training split – say push/pull/legs – and then they build their program around the split. This is putting the cart before the horse. It's backward. Your training split is not a stimulus that your muscles respond to. Training frequency and volume are. You should optimize these variables that determine the stimulus for muscle growth and then create your training program to accommodate those variables.

For example, if you determined that you want to train each exercise 2x per week and each muscle 4x per week, and you want to the gym 6x per week, then it logically follows that you need at least a 3-split. This 3-split doesn't have to have a catchy name like push/pull/legs (which would not fit our criteria, as it would only train each muscle twice per week). There are no restrictions other than they you have 3 different workouts, each exercise appears on only one of those days and each muscle is trained on 2 of the 3 different days. Concretely for your biceps, you could do chin-ups in workout A, Bayesian curls in workout B and no hard biceps training in workout C. Design the program for every muscle group in this manner, put it all together and you have your base training split.

Optimizing the volume distribution

After you set up your base training split, you can often reconfigure it a bit to optimize your total training volume. Zourdos et al. (2016) studied a great example of this in competitive powerlifters. The researchers compared 2 training programs that were identical in all ways except the order of their training days. Both did 3 full-body workouts per week on Monday, Wednesday and Friday, but one group did them in the order of hypertrophy → power → strength (HPS), whereas the other group did hypertrophy → strength → power (HSP). The HPS order resulted in a significantly higher total training volume load than the HSP order, significantly greater bench press strength gains and meaningfully greater effect sizes for the squat and powerlifting totals. The greater total training volume is the most obvious reason for the greater strength gains. The higher training volume in turn is the likely result of placing the easier power workout before the most important strength workout rather than before the double rest day. Power work is much easier to recover from than strength work, as the very high movement velocity inherently prevents high mechanical muscle tension or close proximities to muscle failure. Only one workout in this split will have 2 rest days afterwards, so this should be the most strenuous workout, not the easiest workout.

In conclusion, the order in which you perform the days in your program can affect your total weekly training volume. You generally want to schedule your workouts such that you maximize your total weekly training volume load. Concretely:

- If you have unequal numbers of rest days in your training split, perform your most strenuous workouts before those rest days to make optimal use of that extra recovery time.
- To maximize whole-body muscular development, spread your sessions across the week as equally as possible.

- If some of your workouts are easier than others, perform your most important workouts (training priority exercises or muscle groups) after those easier sessions so that you're relatively unfatigued.

For maximum whole-body muscular development, you often want to spread your sessions and training volume across the week as equally as possible. Each workout should thus generally have a similar number of sets per muscle group as other workouts in which you train that muscle group. However, this is not always possible in practice. For example, if your optimum training volume is 17 sets per week for your hamstrings and you want to train them 3x per week, one session must have a different number of sets than the others. Also, as we'll discuss in later modules, some exercises can be more difficult to recover from than other exercises.

Estimating training status

So far in the course we've seen how both diet and training program design should change as someone gets more advanced. But what constitutes 'intermediate' or 'advanced'? Training advancement can be seen as someone's position on the continuum of untrained to someone's maximum muscular potential. Thus, you should relate the individual's level of strength and muscle mass to their genetic potentials. The closer someone is to their genetic limitations, the more advanced they are. Since someone's level of advancement depends on how much of their genetic potential they have fulfilled, we must first estimate how much genetic potential someone has in the first place.

➢ Lecture [optional]

Program customization

Note: The lecture shows the calculator in spreadsheet format, but you get access to a better calculator online.

Genetic muscular potential

Genetics matter for strength sports. It's easy to think of 'that guy' that doesn't squat because his legs get too big or the female Instagram model that only does bodyweight workouts and yet still has a better booty than you do after years of serious lifting. However, these are the outliers. All in all, genetics and environmental factors contribute about equally to muscle strength-related phenotypes and adaptations to exercise. Most aspects of our bodily functioning are ~40-60% genetically determined. Certain aspects, like your eye color and whether you have boobs or a penis, are of course more fully genetically determined, but the ~50% figure is remarkably constant for other traits that have an obvious environmental influence as well, like your personality or apparently how strong you are.

Genetic influences of training success are also not necessarily outside of your control. Certain genes may not influence the potential for muscle growth or strength development directly but rather influence motivation or willpower, which affect how serious someone takes their training and nutrition, and that then mediates the relationship between having those genes and being able to grow muscle.

Most importantly, the ~50% genetics figure is based largely on untrained or only recreationally active individuals. If we could factor in how much strength training someone does, and how smart they go about it, it's safe to say the figure would drop dramatically.

Then again, can someone that starts off super scrawny ever really develop a great physique? In other words, does someone's baseline muscle mass when they're untrained predict their muscular potential?

Baseline muscle mass

You may expect that how muscular or strong someone is before they start lifting is a strong predictor of their ultimate potential. If they're born jacked, surely, they must get über jacked if they take up lifting? This doesn't seem to be the case. The relationship between untrained baseline muscle mass and muscle growth is weak.

- Ahtiainen et al. (2016) found that baseline body composition and strength level did not predict subsequent muscle growth and strength development during strength training in previously untrained individuals, even though there was marked variation in the response to strength training. Certain 'high responders'

had a 30% increase in muscle size and a 60% increase in strength, whereas certain 'non-responders' actually *lost* 11% muscle size and 8% strength.
- Mobley et al. (2018) studied what separates high and low responders to strength training and found that high responders tended to have a bit *less* muscle mass before they started lifting than the low responders. This makes sense if you think about it from the perspective that the more muscle you already have, the harder it is to gain more. This diminishing-returns principle seems to be stronger than the genetic effects that cause someone to have high baseline muscle mass.
- In identical twins, baseline fat-free mass also does not predict the increase in fat-free mass during overfeeding (without exercise). However, baseline FFM did predict the ratio of fat mass to FFM, indicating they had better nutrient partitioning and an easier time putting on lean mass without getting fat in the process.

Many other studies find there's no significant relation between how much muscle you have before you start training and how quickly you'll gain muscle when you take up training. In trained individuals, the trend is even that smaller muscles tend to grow *faster*, likely because they're relatively less developed. We've compiled a full research overview here if you're interested.

Somatotyping

Another common idea about muscular potential related to baseline muscle mass is that we can classify people into so called somatotypes that differ in their ability to gain fat and muscle. Ectomorph, mesomorph, endomorph, you've probably came across these terms. In the article below we'll summarize what you need to know about somatotyping.

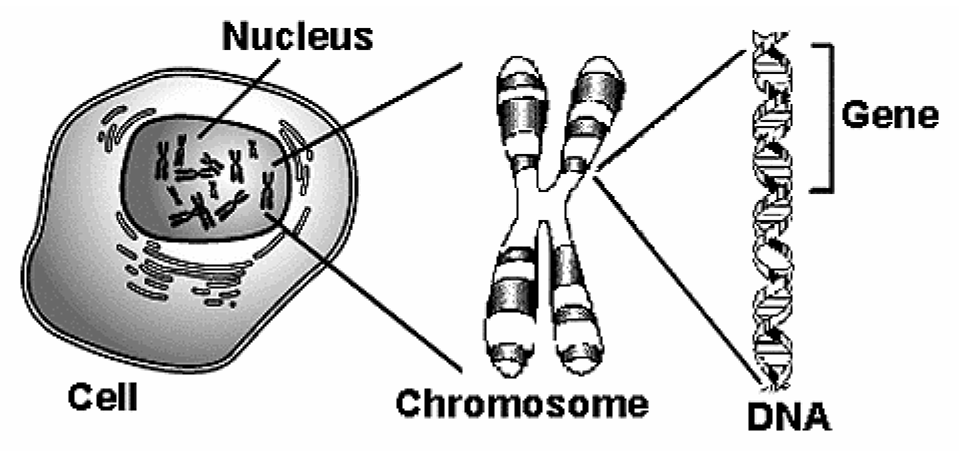
➢ Article

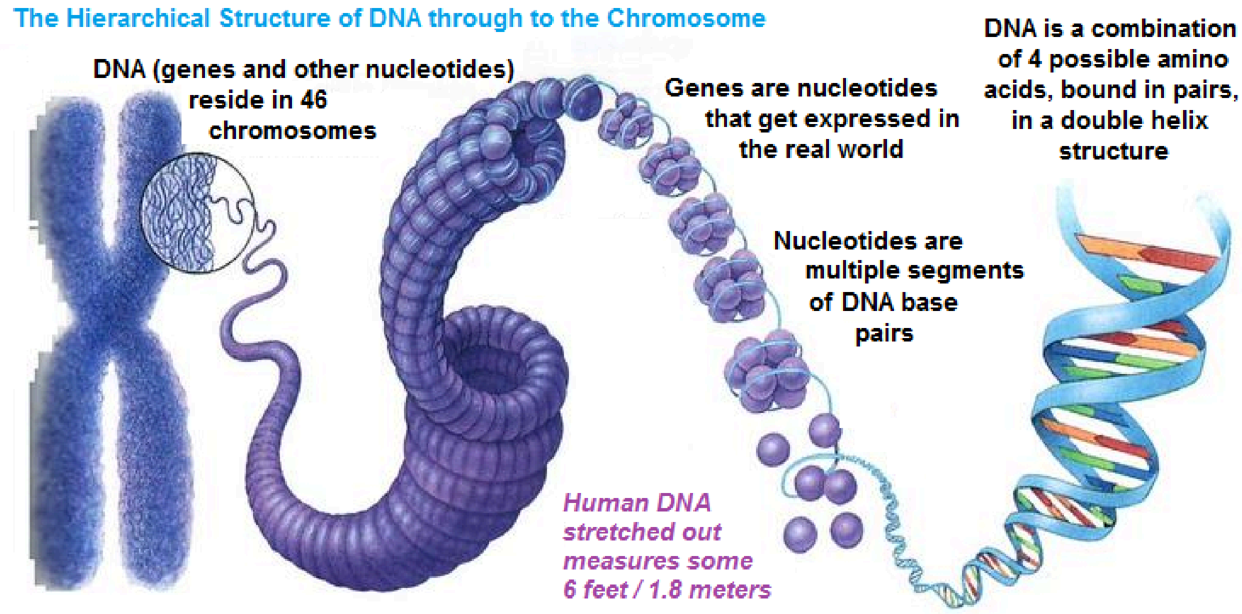
[Endomorph, ectomorph, mesomorph: what does it mean for your diet and workout?]

In conclusion, we cannot predict how good someone's genes are for strength sports based on their starting muscle mass or body composition. How then can we determine if someone has good genes? The most straightforward way to determine this would seem to be a DNA test.

DNA testing

Inside cells with a nucleus – a cell core – lie chromosome pairs that contain your DNA. DNA is basically the blueprint that your cells use to construct your body. Your DNA is composed of many genes that together make up your genome. Each gene encodes information, a little blueprint, about specific aspects of your body.





Many companies advertise such a service these days: you identify someone's genes and that will tell you how someone should eat and train. However, there are many problems with these kinds of tests that limit their practical usefulness.

- Many tests only look at a limited number of your genes. The Human Genome Project has identified over 20 *thousand* genes. So even if you're looking at particularly interesting genes, it's still much like looking at a single computer chip and trying to figure out how the entire computer works based on that single chip.
- Just knowing the configuration of your genes does not necessarily tell you what their practical results in your body are. Many genes share information and interact with each other to encode the structure of any part of your physiology. You may have a gene that has the capacity to encode your body with cells that can produce extremely high rates of muscle proteins, but it may be useless because the rate limiting factor is a certain enzyme you don't have enough of. It's like trying to predict how a soccer team performs by only looking at the stats of the individual players without knowing how their work together as a team.

- Science is still in its infancy in terms of figuring out what each gene does in the first place. Research is greatly limited by not being able to conduct many controlled experiments in humans, because it's difficult to implant genes or knock them out. We're largely limited to associative findings right now, e.g. 'most world class sprinters have this gene, so this gene is probably good for sprinting'.

The latest 2022 meta-analysis could explain 44%, 72% and 10% of the response variance in aerobic, strength and power gains from training based on someone's genetics in untrained individuals. In terms of 'talent scouting' ability, these results are almost useless for power, disappointing for endurance but promising for strength. Yet even for strength, being able to explain 72% of the variance in people's gains is not that great at the group-level. This analysis looked at 3,012 participants from 29 studies and tried to predict averages. Within individuals, the accuracy decreases dramatically. For what it's worth, the gene groups with the highest predictive power for strength development, in order, were ACE, ACTN3, AKT1, COX4I1, mTOR and VEGF-A, but the results were conflicting for each individual gene. Since we can't even predict how well an individual will respond to training in general, we're nowhere near being able to determine how an individual should train. This requires predicting not only someone's overall genetic potential, which is roughly what we're currently still figuring out, but also how someone's genes interact with program variables such as training volume. A consensus statement from genetic researchers in December 2015 concluded: "The general consensus among sport and exercise genetics researchers is that genetic tests have no role to play in talent identification or the individualized prescription of training to maximize performance."

So how come DNA testing is so popular these days? It's the same scam as fortune telling, hand reading or looking into a glass ball. As the above consensus statement concluded: “There is concern among the scientific community that the current level of knowledge is being misrepresented for commercial purposes.”

A 2016 review paper similarly concluded: “currently available genetic tests [...] cannot predict athletic performance with any accuracy.”

The state of DNA testing in the field of nutrition (nutritional genomics) is similar [1, 2].

In short, the science isn’t there yet for individual DNA testing with relevant practical applications for training programming or nutrition.

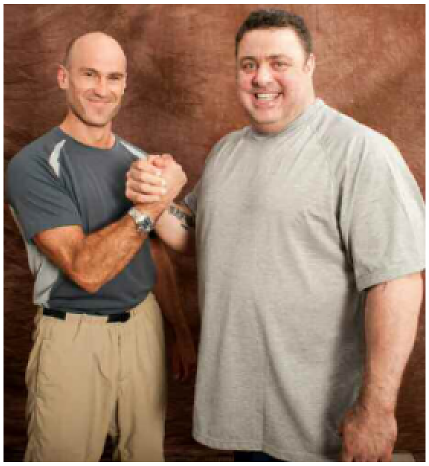
For all the scientific knowledge we have gathered, the best predictor we have of someone’s muscular potential is quite a crude one: frame size.

Frame size

“I started weight training at age 18. Right from the start I was strong. The first time I ever lifted I squatted 500 pounds and deadlifted 600 pounds. Lads from the gym thought I had trained before, but no, it was my first time. That's when it all started.”

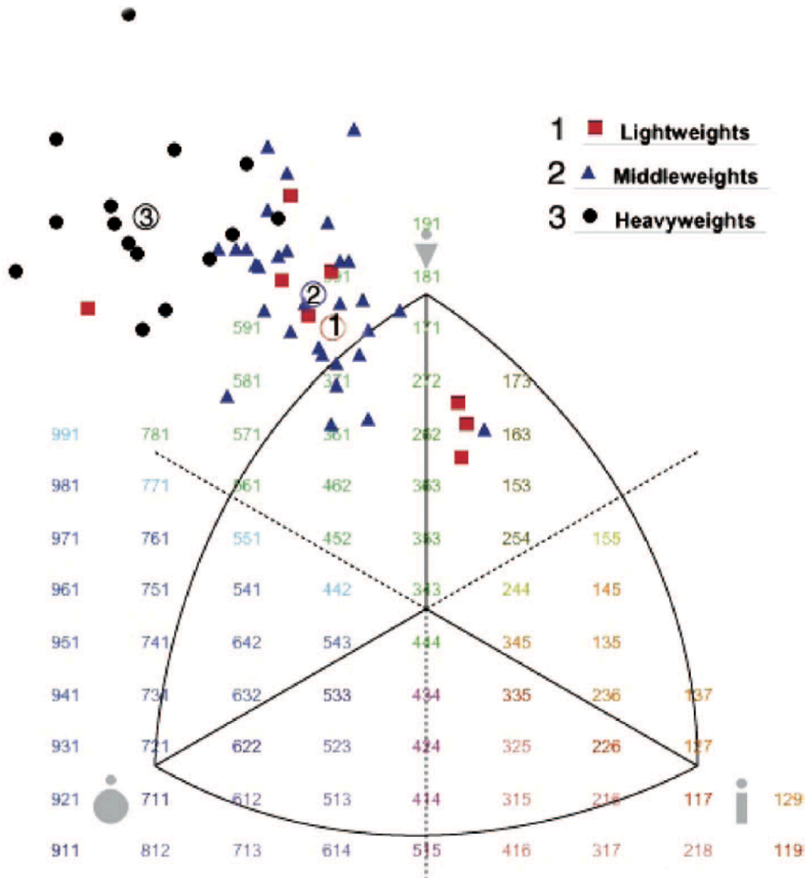
- Andy Bolton

What made the untrained Andy Bolton stronger than most lifters will ever be? For one thing, his build. The image below shows what Andy looks like next to Pavel Tsatsouline, who is himself renowned for his feats of strength. Andy dwarfs Pavel not just because he has a lot more muscle and fat mass but also because his skeletal frame is immense.



Having a large skeleton with thick bones helps support muscle mass. The thicker your frame, the more muscle you can build around it. It's like a clothing rack: you can hang more clothes onto a big rack. Frame size correlates with body composition, so most people with big joints and bones are naturally more muscular than their slimmer built counterparts [1, 2, 3]. People with a larger structure ('mesomorphs') are also stronger on average than people with a smaller structure and they gain muscle faster during weight training. Top Olympic weightlifters, powerlifters and bodybuilders all have large bone girths, and frame size is a good predictor of success in all 3 sports [1, 2, 3].

A study by Keogh et al. (2006) measured the bodily dimensions of Oceania's national and higher-ranking powerlifters compared to various scientific standards. The majority of powerlifters literally scored off the chart on the indices: see image below. One guy scored 14.8 on what is supposed to be a 7-point scale(!)



Moreover, people who start off big also generally respond well to higher training volumes. [High baseline lean body mass predicts greater benefits of higher vs. lower training volume within individuals](#).

Contrary to the natural freaks who are large all over, most people have good and bad body parts. It's possible for someone to have broad shoulders but tiny arm bones, for example. This allows you to assess naturally weak body parts and exercises. This is also one of several reasons why structural balance theory is flawed: you can't always expect different people to have similar strength ratios between all exercises.

As an objective guideline to classify someone's frame size, you can look at someone's wrist and ankle size and use those as a proxy for the person's total frame size. The following reference data from the US National Library of Medicine can be used for wrist size. As a rule of thumb, women's wrists are ~6 inches or ~15 cm and men's wrists are ~7 inches or ~17.5 cm.

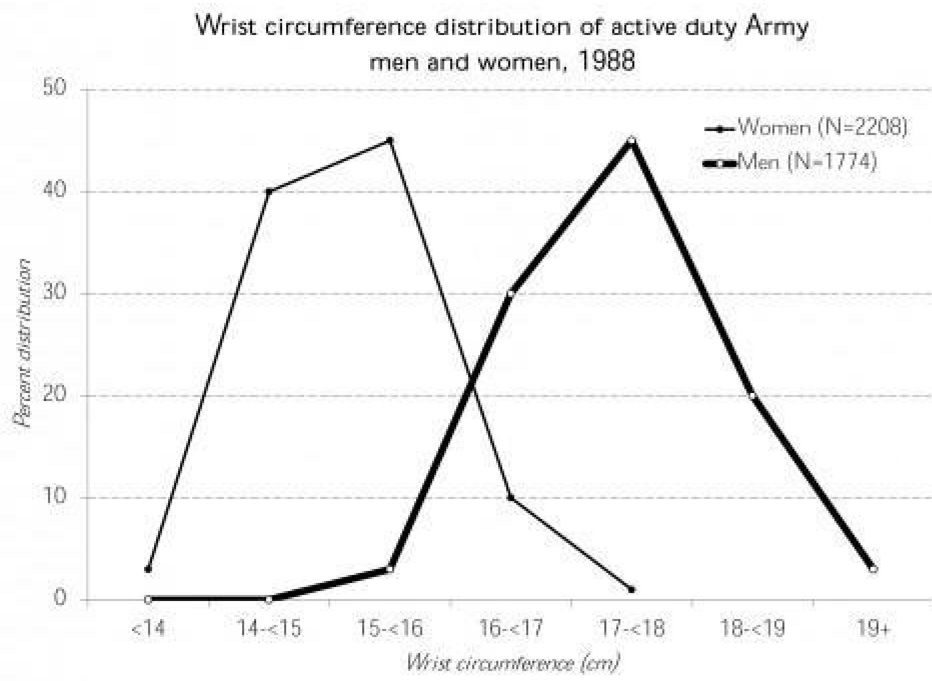
Women

- Height under 158.5 cm (5'2")
  - Small = wrist size less than 14 cm (5.5")
  - Medium = wrist size 14 – 14.6 cm (5.5" - 5.75")
  - Large = wrist size over 14.6 cm (5.75")
- Height 158.5 – 167.5 cm (5'2" - 5'5")
  - Small = wrist size less than 15.2 cm (6")
  - Medium = wrist size 15.2 – 15.9 (6" - 6.25")
  - Large = wrist size over 15.9 cm (6.25")
- Height over 167.5 cm (5'5")
  - Small = wrist size less than 15.9 cm (6.25")
  - Medium = wrist size 15.9 – 16.5 cm (6.25" - 6.5")
  - Large = wrist size over 16.5 cm (6.5")

Men

- Height over 167.5 cm (5'5")
  - Small = wrist size 14 – 16.5 cm (5.5" to 6.5")
  - Medium = wrist size 16.5 – 19 cm (6.5" to 7.5")
  - Large = wrist size over 19 cm (7.5")

As an additional reference with metric values, the following survey data from the US military can be useful.



For ankle size, we have the research from [Karakas & Bozkir (2007)]() of average ankle circumference in medical students. Note that overweight individuals may have inflated ankle sizes: fat should not be mistaken for good genetic potential to build muscle mass.

- Ankle females: 21.9 ± 1.3 cm (8.6")
- Ankle males: 23.5 ± 1.5 cm (9.3")

In a US army survey, the 95% confidence interval of ankle circumference for men was 20.2 – 25 cm; for women it was 19 – 22.6 cm.

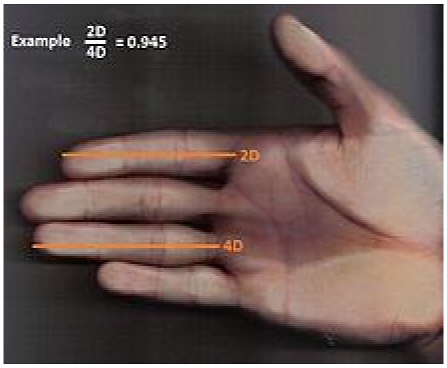
In addition to someone's frame size, there are multiple other potential indicators of someone's muscular potential that show promise but either explain very little variance or we have very little research on.

1. Secondary sex characteristics

Throughout childhood and especially during puberty, testosterone produces masculine body features. These include large vocal cords, a big Adam's apple and a deep voice, body hair, especially on the face, forearms, abs and chest (though later in life there is androgenic alopecia, as you learned in the hair loss module) and a more square facial structure. As you learned in the course modules on dietary fat and AAS, testosterone is a potent driver of muscle growth, so androgenic body features may correlate with someone's muscular potential. For example, you can predict a martial artist's fighting ability from how square their face is. However, this may not necessarily be due to physical attributes but also due to behavioral differences, such as greater aggression and reduced fear.

2. The 2D:4D ratio

This one is less intuitive. The shorter your index finger and the longer your ring finger, the higher your prenatal exposure to testosterone likely is. Men typically have ring fingers that are a bit longer than their index fingers, whereas women tend to have roughly equally long index and ring fingers.



If you have a low 2D:4D ratio with a long ring finger, you tend to have a higher potential for strength sports. Research has found this relation in a wide range of sports and physical activities [2], even sumo wrestling. It also affects your health and psychology as shown in the overview from an older Wikipedia copy below.

	Low digit ratio	High digit ratio
Physiology and disease		• Lowered sperm counts[42] • Increased risk for heart disease in males[43] • Increased risk of obesity and metabolic syndrome in males[44] • Reduced risk for prostate cancer[45] • Reduced birth size in males[46][47]
Psychological disorders	• Increased rate of ADHD in males[48][49][50][51] • Increased rate of Autism Spectrum Disorders and Asperger syndrome	• Increased risk for depression in males[55] • Increased rate of schizophrenia[56]

	(when comparing digit ratio to general population)[52] ● Reduced risk in females for anorexia nervosa[53] and in males for eating disorders[54]	● Increased rate of psychopathy in females[57] ● Reduced risk of alcohol dependency[58] ● Reduced risk of video game addiction[59] ● Increased anxiety in males[60]
Physical and competitive behavior		● Reduced performance in sports[61] ● Reduced financial trading ability[62] ● Right handedness skills[63] (inconclusive)[64]
Cognition and personality	● Assertiveness in females[7] ● Aggression in males[15][65] ● Masculinity of handwriting[66] ● Perceived 'dominance' and masculinity of man's face[67][68]	● Personality traits correlated with digit ratio, higher being more feminized[72][73][74]

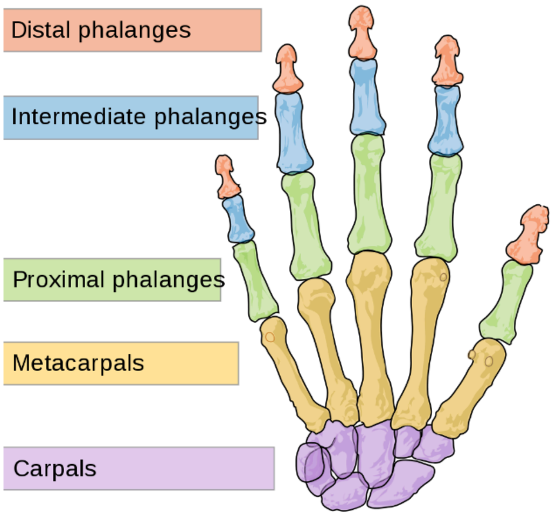
	• In an orchestral context, rank and musical ability in males[69] • Academic performance[70] • Math ability[71]	• Paranormal and superstitious beliefs among men with a higher digit ratio[75] • Higher exam scores among male students[31][76]
Management	• Leadership[77] • Innovation[78]	•
Sensory perception		• Smell perception[79] • Color perception[80] • Tactile perception[81]
Sexual orientation	• Lesbians have a lower digit ratio, on average, than heterosexual women[82][83][84][85][86][87][88][89][90][91][92][93]	• Sexual preference for more masculine men among women[82] and gay men[94] with high digit ratio; a preference for a masculine facial type means a

		more "feminized" mindset. • Lesbians are more likely to be femme and less likely to be butch with a high digit ratio.[84][95] Identical female twins discordant for sexual orientation still show the difference (lesbian less than straight, on average) in digit ratio.[86][96] • Homosexuality for men,[85][97] but this is disputed,[92][98] and subject to geographic variations[99]

2 of Menno's male clients. Left: excellent estimated genetic potential. Right: poor estimated genetic potential. Note the corresponding difference in hair growth and joint thickness.

Of course, you cannot tell simply based on someone's fingers if someone is homosexual or how good of a sumo wrestler they are. The 2D:4D ratio has some predictive power in large groups, but at the individual level it's a weak indicator of genetic potential. If you're not concerned with finetuning all minutiae in your program, you don't need to look at it.

That said, your hand will not only tell you what your 2D:4D ratio is. Middle phalangeal hair, especially on the ring finger, is another indicator of androgen exposure [2]: people with more hair on the second-to-last bones of their fingers tend to have higher prenatal testosterone exposure and higher testosterone levels and thereby presumably better genetic muscular potential.



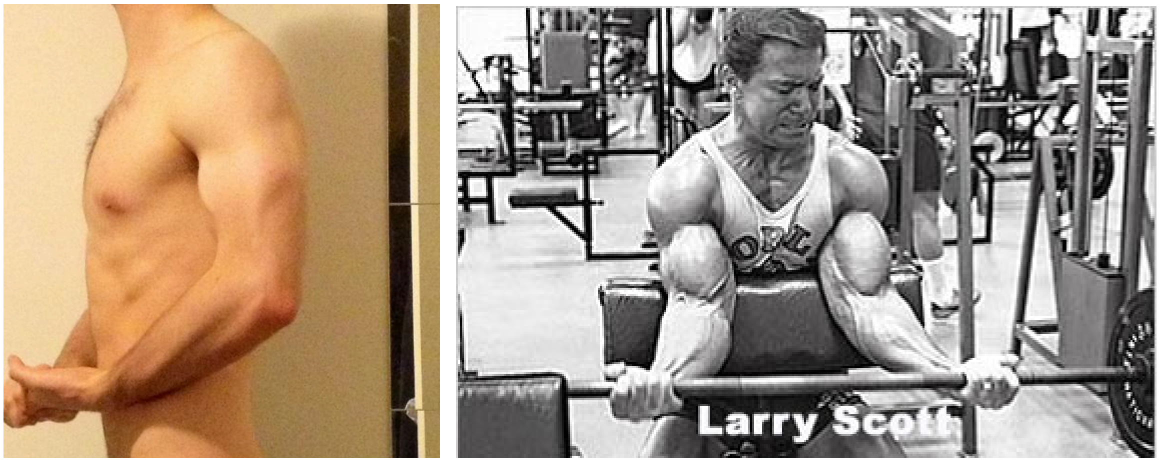
The hand is also a good place to assess a person's skeletal frame size due to the extremely high number of bones in the hand.

Astute readers will note that Menno specifically ask for his clients' right hands in his intake form. There is some evidence that the right hand is a better predictor of prenatal testosterone exposure than the left.

The 2D:4D ratio is best measured with the hand flat on a surface with the palm facing up. However, there's only 0.1% more error with the palm down when the arm is straight and then you can also assess mid-phalangeal hair when the palm is down.

3. The fullness of your muscle bellies

Longer muscles have more mass potential than shorter ones. They are literally longer after all. As a proxy, flex one of your elbows to 90° and see how many fingers you can put in between your elbow and your biceps. 0 is amazing, 4 is terrible.



Compare the insertion points of one Menno's clients' biceps above (left) to that of Larry Scott (right) and it's not difficult to see which one can carry more mass.

4. Your birth weight

It's said that ancient warrior Spartans abandoned newborns that were deemed unfit to be soldiers. The idea was that scrawny babies could not possibly grow up to be great soldiers. Science has supported this idea to a degree: the bigger you are as a baby, the more muscular you're likely to become as an adult. Birthweight also predicts muscle strength, flexibility and agility. However, there's no research on whether this also directly influences muscle growth in response to training. We do know it's a myth that being large as a baby predisposes you to obesity.

As a reference, the average Caucasian newborn weighs 3.4 kg (7.5 lb) and anything under 5.5 lb. (2.5 kg) is considered clinically underweight. Detailed reference data for infant weights of both genders can be found in the National Center for Health Statistics Data Table of Infant Weight-for-age Charts.

5. Ethnicity

Politically incorrect as we may find it, racial phenotype may serve as a proxy for someone's potential for strength sports. In general, we can distinguish between the following phenotypes in order of baseline fat-free mass index without strength training and controlling for activity level and nutritional status: Black > Caucasian/Hispanic > (South) Asian [2, 3, 4, 5, 6, 7, 8, 9]. However, there is very little research on if these baseline differences also appear in the responsiveness to strength training. Knox et al. (2017) found that South Asians gain less lower body but not upper body strength from a given strength training program. In contrast, Alkhayl et al. (2022) found South Asians gain just as much lower body strength but not upper body strength from a given strength training program. Total 1RM strength, muscle growth and muscle protein synthesis rates did not differ between the ethnic groups. Thus, it seems that any average racial group differences are much smaller than the within-race variation between individuals when it comes to the ability to build muscle.

Determining training status: application

The following calculator can help you estimate how muscular and strong someone could possibly get. It also includes reference levels from the scientific literature to determine how advanced they are at their current level of muscularity.

You should ideally assess genetic potential on a per-muscle basis. For example, it is typical for men who have been training like traditional bros to have relatively underdeveloped posterior delts, hamstrings, glutes and calves and have highly advanced pecs and arms. The calculator can help you identify weak and strong muscle groups.

➢ **Training status calculator**

➢ **Menno's intake form**

In practice, you cannot always use someone's fat-free mass index (FFMI) to estimate how advanced they are, because you need to have a reasonably reliable estimate of their body fat percentage before you can calculate their FFMI. For these cases, you should learn how to estimate someone's level of muscularity visually based on their photos and, importantly, based on their strength level. Since strength and muscle mass correlate very well in practice in natural trainees (see course module on understanding muscle growth), the Kilgore-Rippetoe-Pendlay strength standards are often a more practical measure of training status than measures of someone's muscularity. These standards are based on a very large sample size of serious strength trainees and have proven over time to constitute a realistic frame of reference.

The FFMI and strength standards are based on average genetic potential. There is probably some selection bias in that people with better genetics for strength and muscle growth are more likely to take up strength sports in the first place and thereby become part of the reference of what's average, but since we are normally exclusively dealing with this population, the estimates are valid for our purposes. In theory you thus want to adjust someone's strength and FFMI level for their genetic potential. It is not someone's absolute strength level that affects how much more strength and muscle someone can gain but how developed their muscles are relative to their potential. Someone may have an above average FFMI and intermediate level strength with barely any lifting experience. They are then logically a novice, just one with good genetics.

However, good genetics may function much like training experience inside the muscles. Individuals who gain muscle relatively fast have been found to have more satellite cells than hardgainers and greater upregulation of growth factors after training, whereas low-responders have excessive post-exercise inflammation. As you've learned, satellite cells and growth factors are part of the muscle repair and growth process. Excess inflammation on the other hand impairs recovery. As such, individuals with great genetics probably recover faster than hardgainers, much like trained individuals recover faster than untrained individuals. In line with this, individuals with higher natural lean body mass respond better to higher training volumes. In practice you can thus reasonably use someone's absolute FFMI and strength level as a proxy for their training status. It may not matter that much if they're strong because they have a lot of lifting experience or because they have good genetics: in either case the muscles can probably handle a higher training volume.

By factoring in someone's genetic potential into their estimate of their training status, we can simplify the customization process to just determining an individual's training status based on the Kilgore-Rippetoe-Pendlay strength standards and the individual's FFMI.

In conclusion, you can determine someone's training status reasonably well simply by checking their strength level against the above strength level chart. To assess muscularity specifically, input their data in the Henselmans FFMI calculator. Unfortunately, we don't have enough data to classify FFMI levels into novice/intermediate/advanced categories like we have for strength, but based on the following chart, you should be able to make a reasonable estimate.

28.0	Largest natural trainee ever scientifically documented
25.4	World class natural pro bodybuilder
24.9	Upper limit for most people's genetics
24.8	Average steroid user
22.6	Internationally competitive bodybuilder
21.8	Competitive power athlete
18.9	Average Caucasian

Symmetrical development

Another aspect of individualizing a training program is ensuring symmetrical muscular development. Most people find symmetry to be aesthetically pleasing, so most people want to have a body in which all muscles have approximately the same size on both sides. *Perfect* symmetry is not practically possible, especially not for muscle strength. No matter what you do, one side will typically remain a bit stronger than the other. For right-handed individuals, it's normal to be able to perform a few more reps with your right-hand side than with the left-hand side for most exercises. The motor cortex, the part of the brain that coordinates our muscles, is more experienced at using this side and this greater neural efficiency translates into greater strength. It's thus practically impossible to achieve perfect symmetry in strength. Strength asymmetries up to 10% are generally considered normal.

However, major asymmetry in strength is not just a cosmetic problem: it may also cause you to rely more on that side during bilateral movements and predispose you to injury and further asymmetry.

To ensure symmetrical development, it's useful to include unilateral (one-armed or one-legged) exercises in a program, or at least in most of a person's programs over time. Unilateral exercises allow you to train each side individually and thereby equate the training volume per limb. As a default strategy, start any unilateral exercise with the weaker side and then perform the same number of reps with the stronger side. For natural trainees, equating training volume like this is often enough to ensure reasonably symmetrical development. Since a muscle grows slower and slower the closer it gets to its muscular potential, any asymmetries in size generally even out over time when you equate training volume per limb during a significant portion of the training program. In the end you should reach each side's maximum muscular potential and then you'll have the highest symmetry you can achieve anyway. The more asymmetrically developed one side is, the more unilateral exercises you should include to balance this out, but normally just a single unilateral exercise per muscle is enough.

In case one side is much stronger and visually bigger than the other, you can reduce the more developed side's number of training sets to maintenance level while you keep the less developed side's volume at the optimal level. A good rule of thumb is to reduce the more developed side's training volume to a third of the optimal volume based on the course principles.

Equating volume with unilateral exercises works well to correct asymmetries in which one side is both stronger and more muscular than the other, but sometimes one side is bigger but weaker or smaller but stronger. For these rarer types of asymmetry, you need to differentially train the body parts for strength vs. size. By far the simplest method to train more for size vs. strength is training intensity. As you learned, higher training intensities significantly benefit the development of muscular strength, but on a set-by-set basis with the same proximity to muscular failure, there is for most individuals little difference in muscle growth between 30-85% of 1RM. Thus, if one side's bigger but weaker than the other, you can train it with an intensity of 85-100% of 1RM compared to 30-60% of 1RM for the side that's smaller but stronger. For example, if as an intermediate level trainee your right quadriceps is visually bigger yet weaker than your left one, you can do split squats and leg extensions with an intensity of 90% of 1RM for the right leg while you do them with an intensity of 30-70% of 1RM for the left leg (e.g. 30% for leg extensions and 70% for lunges). Your right quad will gain strength more quickly but size probably more slowly, thereby correcting the asymmetry over time.

In theory you can also manipulate other program parameters, such as the rest interval, to further emphasize strength vs. muscle growth, but in practice natural trainees rarely ever need to.

Underdeveloped body parts

Many trainees are worried about having underdeveloped muscle groups. Often, these concerns are not objectively founded. For example, men often think their arms or pecs are underdeveloped yet rarely worry about their middle traps or glutes. Wanting for a body part to be bigger is not the same as having an objectively underdeveloped body part. A muscle's objective level of development is best quantified by its level of development relative to its genetic potential. If you feel you may have underdeveloped body parts, you should use our training status calculator. It will estimate not just your muscular potential but also the relative development of your body parts.

If you have a genuinely underdeveloped body part, say more than 10% underdeveloped, you should evaluate your training program for that body part.

- Are you allocating enough volume to it? Calculate your weekly set volume for those vs. other muscle groups.
- Are you training all its major functions?
- Are you prioritizing the body part sufficiently with your exercise order?

If not, adjust your program accordingly.

If your program is already optimized for all muscle groups, you generally don't have to worry about your ratios of muscular development as a natural trainee. Everyone has a different anthropometry: our bone lengths differ, our muscles insert on different locations and we have different genetic strengths and weaknesses. To the extent that your body parts could be more evenly developed, this will naturally balance out over time as you fulfill your genetic maximum muscular potential. The more advanced a body part is, the more slowly it will grow, so less developed body parts will naturally catch up with the rest if you train all body parts equally.

Body part specialization training is generally only a consideration for trainees that are time-constrained. If you can only train twice per week, for example, it will probably be difficult to train each muscle group with its required volume for maximum muscle growth. In this scenario, you could decide to train your less developed body parts with a higher training volume than more developed body parts.

It's important to realize that muscle growth is a local process, so you cannot take volume from your glutes and allocate it to your biceps. If your biceps volume was already optimized, this will only cause overtraining and *reduce* biceps growth. Whether you train your glutes or not does not inherently affect the development of your biceps. If anything, training your glutes might improve biceps growth via central mechanisms, as you learned in the course module on Understanding Muscle Growth.

Work capacity

Another way to customize someone's program is by looking at the person's work capacity.

➢Lecture [optional]

Program customization based on work capacity

Work in exercise science is the same as that in physics: it's a measure of the energy it took to move an object with a certain force over a certain distance in a certain amount of time. In the case of weight training, it's a measure of energy expenditure during the lifting of the weight. More simply, within the practical scenario of a series of training sets for an exercise, your work capacity scales linearly with the number of repetitions you do across all sets.

For example, if a person does 4 sets of squats to failure with her 12RM and the repetitions go like 12, 12, 11, 11, that shows great work capacity. Many individuals lose repetitions across every set when they train close to failure. If someone's repetitions go like 12, 6, 3, 2, that means work capacity is low.

You can quantify work capacity precisely by calculating a measure like the average percentage repetition drop-off per set. A common fatigue index used in the scientific literature is the Sforzo and Touey (1996) formula, which gives a percentage decrease in work (W) output across sets.

$$\text{Fatigue Index (\%)} = ((W_{\text{first set}} - W_{\text{last set}}) / W_{\text{first set}}) \times 100$$

$$\text{where } W = \text{work} = \text{load} \times \text{repetitions}$$

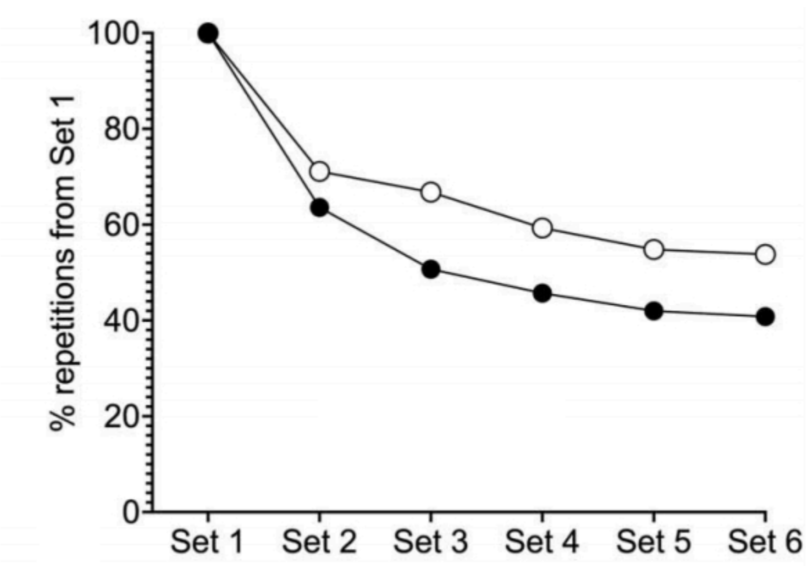
For example, if you trained with 90 kg and you performed 11 reps in your first set and 7 reps in your last set, your fatigue index across those sets was $(((90 \times 11) - (90 \times 7)) / (90 \times 11)) \times 100 = 36.4\%$.

If the weight is constant across sets, we can simplify this formula to the percentage drop in repetitions from the first to the final set. For example, going from 10 to 2 repetitions equals a fatigue index of 80% and going from 10 to 5 reps amounts to 50% fatigue.

The fatigue index tells you how much acute neuromuscular fatigue someone accumulated. Many trainees estimate their fatigue subjectively, which is often terribly inaccurate, as we'll discuss in the periodization module. The fatigue index is the best objective measure we have of how fatigued a muscle truly is. It logically follows that the fatigue index can help us decide whether to increase or decrease training volume, but there is unfortunately no direct research testing this. Anecdotally, it works well. If someone does not develop much fatigue during an exercise, they may be able to handle more sets for that exercise. Someone that already gets extremely fatigued from that exercise is less likely to benefit. They may have trouble recovering and the additional set will inherently pose less of a stimulus for them, because they won't be able to complete as many reps, so the total added tension on the muscle is lower when you're more fatigued. Neuromuscular fatigue reduces a muscle's ability to contract and produce tension (= force). The beauty of the fatigue index test is that it doesn't matter *why* their reps decrease. If someone just doesn't train very hard and thereby accumulates little fatigue, they can compensate for their lack of effort per set by adding more sets (although in practice this population is often just as reluctant to increase volume as to train close to failure). A person that trains with high effort but has amazing recovery capacity and therefore still has a high work capacity should still be able to handle more volume. Regardless of whether someone's fatigue is primarily influenced by their rest intervals, their proximity to failure or their physiological recovery capacity, in the end the total fatigue is what decides how much stimulus they can still get from an additional set and how easily they'll recover from it.

Here's how you can use the fatigue index concretely.

- Less than 20% fatigue for women or 30% fatigue for men across multiple sets is very low. On average in the literature, people accumulate that much fatigue from a single set to failure. If someone consistently stays below this level of fatigue, they should be able to add a set to the exercise.
- A decrease in reps of more than 60% for men or 50% for women is very high. Fatigue tends to plateau at this level, suggesting the fatigue is self-limiting at this point and there's probably not much point in adding more sets. In fact, it's worth subtracting a set from the exercise to see if this affects the rate of progress.



The average number of repetitions trainees can complete across 6 sets with rest intervals up to 2 minutes (black dots) or over 2 minutes (white dots) according to a 2024 meta-analysis.

You generally don't want to change the training volume by more than 1 set per exercise per week, because you need some time to see how progress is affected.

Note that someone's fatigue index is highly individual and influenced by multiple factors. The obvious determinants are training proximity to failure (harder sets cause more fatigue) and your rest intervals (more recovery reduces fatigue). Less obvious effects come from how advanced someone is and whether they're male or female.

1. Training status: Trained individuals have better work capacity than untrained individuals. However, stronger trained individuals have poorer work capacity than weaker trained individuals and strength increases have been found to coincide with loss of work capacity. The stronger you get, the more fatigue you can impose upon your body with each set, yet the more volume you generally need for maximum progress, so good programming becomes more important. "It never gets easier. You just get stronger."
2. Biological sex: Women have higher work capacity than men at lower training intensities (~80% and above) but lower work capacity above ~90% intensities. At intensities below 50%, women can perform up to 88% more reps, i.e. nearly double the volume. So women generally suffer considerably less neuromuscular fatigue during their workouts than men, even advanced female trainees. (See the course module on sex differences for more information.)

You should quickly get a feel for what a representative fatigue index is for a person based on your experience and what you've learned in this module. If you need more reference data though, here's a research overview.

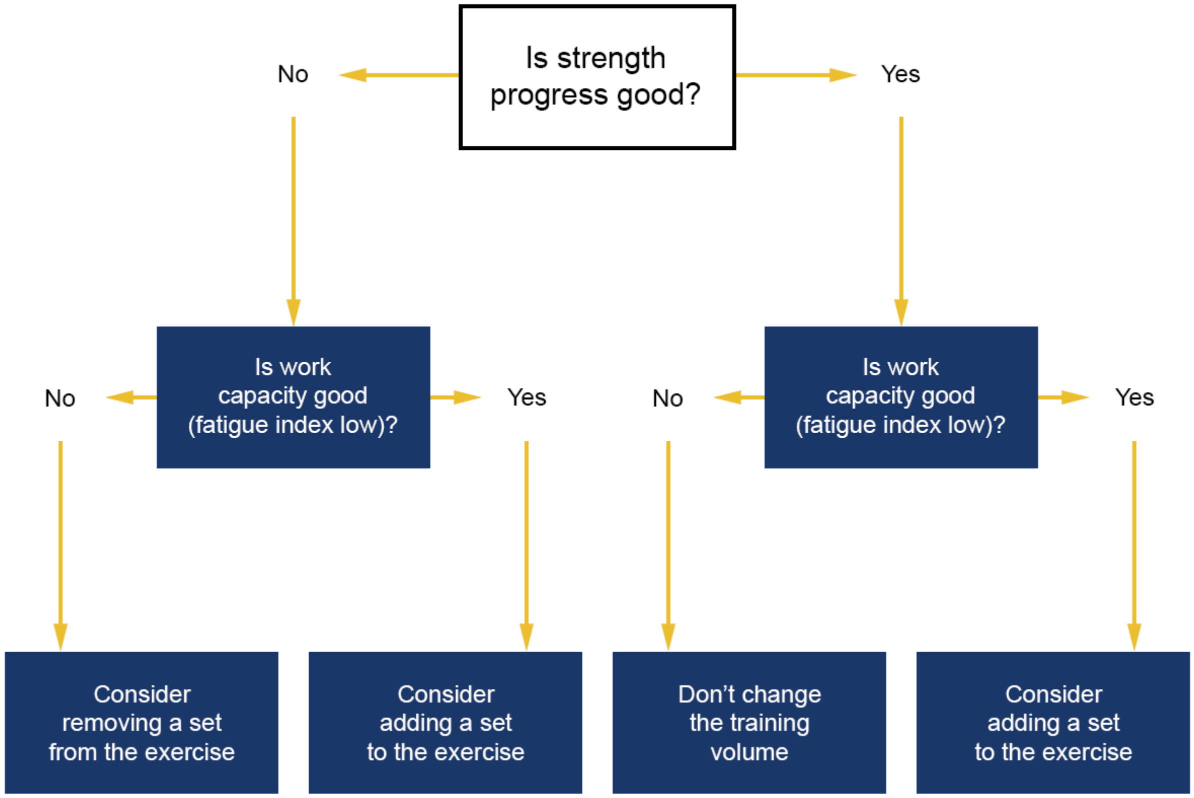
➢ Literature overview

Work capacity / fatigue index reference data

You should interpret the fatigue index within the context of other fatigue indicators, in particular the rate of strength progress. If someone's progressing well in strength, they are evidently recovering and even supercompensating in between workouts, so they are not overtraining and you generally shouldn't decrease the training volume. Volume reductions are generally only physiologically beneficial when progress is poor and fatigue is high, suggesting the volume is excessive for the trainee's recovery capacity.

In addition, it may be worth experimenting with extra rest days or deloads to see if that improves their performance. If you see consistently better progress after rest days or deloads than without them, combined with low work capacity, you should probably decrease the training volume, as they may be overreaching.

You may wonder if you need to test work capacity if you're already using the muscle-specific hypertrophy method. You do, because there is no significant correlation between work capacity and how many repetitions you can perform with a given intensity. Work capacity needs to be measured directly.



A general decision tree to help you adjust someone's training volume based on their work capacity and progression.

Blood type

In mainstream media, you may hear of 'blood type diets'. The idea is that someone's blood type determines how they should diet or train. This is complete pseudoscience: your blood type does not affect what type of diet you respond best to and there's no credible evidence it affects strength training.

Take-home messages

For maximum muscle growth, a training program should have the following parameters.

- Training intensity: 30-90% of 1RM, ideally with the muscle-specific hypertrophy method and higher intensities for compound exercises.
- Training volume: generally in between 10-30 sets per week per muscle group based on someone's recovery capacity.
- Training frequency: at least once per week for every 6 sets of training volume per muscle, increasing up to daily or even bidaily training as training volume and training advancement increase. In practice, many trained individuals can make each workout a full-body training session.
- Your training split should logically follow from your optimized training frequencies and volume, not the other way around. Make the training split fit your optimized parameters for each muscle group and then configure it to maximize the total weekly training volume load.