Starting Strength

Herculean Hypertrophy and Milo's Mass

by

Max Blochowiak

In any field of science, particularly applied sciences, *The Literature*™ does not come out until long after the science has been hypothesized, practiced, and preached. Shamans were curing people long before Fleming discovered penicillin. We can only hope experiments validate that which we have conjured up in our measly brains or learned from the elders, but we are seldom this lucky, as is the case for shamans healing cancer by aligning chakras or whatever it is they do. Resistance training (RT) has been around in its modern form, with barbells and such, for the better part of a century, perhaps a little longer. However, the dumbbell and similar items have been around for thousands of years, and physical training of some form is likely prehistoric. In comparison, *The Literature*™ is in its infancy. Old habits die hard, but sooner or later we have to burn off the deadwood.

Though *The Literature*™ is still young and growing, some of its data are quite meaningful. If The Reader considers himself a trainer/coach/prophet or merely a Student of the Game, he should spend the time necessary to go through this. It will only make him more knowledgeable and well-reasoned. The intention of this article is not to ruffle feathers, but I will not pretend I don't enjoy challenging authority and rustling some jimmies. I want every lifter's training to be optimized, and I certainly would like the trainer/coach golden retrievers to be replaced with Men Who Understand Science. The Literature™ should act as the wind necessary to guide our sails. If we do not wrestle with the science we have no idea which way the wind is blowing. However, this is a lot of information and if The Reader is relatively new it may seem overwhelming.

This will be a Deep Dive into the hypertrophy literature and how we should go about accumulating hypertrophy. I say accumulate because hypertrophy is an anabolic process, not a fixed goal one can achieve. Resistance training is our best tool for inducing hypertrophy along with routine consumption of a caloric surplus, and this post will be concerned specifically with the training prescription necessary to maximize *gains*. As the article continues it will get further in-depth and we shall continue our descent down the rabbit hole. I thought about trying to shorten it by including multiple studies for a single conclusion, explaining less, not writing an article at all, etc. But, the less thorough this is, the more room for interpretation there will be left to the Reader. That is not my goal for this article. I want to remove any chance of an arrow piercing the armor.

One Must Gripe Like He Means It

> "To kill an error is as good a service as, and sometimes even better than, the establishing of a new truth or fact."
>
> – Charles Darwin

The most important variable for a Man of Logic deciphering what *The Literature*™ is attempting to tell us is not understanding p-values or effect sizes, but the ground that leads the man to the study in the first place. Many of the studies below can be claimed by a particular philosophy as evidence for its position, but could also be adopted by another system drawing exactly the opposite conclusion from the same data, with many shades of gray in between. So, the bifurcation in the interpretation stems from the *a priori* belief system already espoused by the Reader, although it manifests as an interpretation issue.

I believe that force production is the basis of our reality. I also believe we improve our ability to produce force in specific ways, centered around a barbell and perhaps a dumbbell or two. This drastically influences how I interpret *The Literature*™.

My bias, which is the correct one to have – I highly recommend it – is looking for data that allows me to further believe that training for strength is the paramount strategy one can use in the gym. This means that if a study can lead me in the direction of offering legitimate strength training as an equally-valid strategy for hypertrophy as, say, bodybuilding-type training, I am going to highlight that fact. I am not going to advocate bodybuilding or high-rep training because it is clear that these modalities do not make us nearly as strong as low-rep training.

For example, many have run wild with some minor implications from a recent Schoenfeld et al. [1] study in order to peddle the idea that we need not use high-loads regularly to achieve maximal hypertrophy or even strength *gains*. The Reader will find this to be patently absurd when the data is laid out later in this article, but it illustrates an inherent problem in concluding what the data actually say. Humans read and interpret the numbers; the data do not conclude themselves.

If, for instance, when I come across a study purporting that low-rep sets caused as much hypertrophic response as moderate- or high-rep sets, I am going to snatch this up as evidence that we should focus on low-rep sets. I will do this because the overarching philosophy leading me to this study is skewed toward force production. Furthermore, I am always going to side with the training that will allow us to kill two birds with one stone. I hate birds.

My other bias is toward training tools, specifically the barbell. There are features of the barbell that no other tool in the world can achieve, and it is the most potent device we have for driving both strength *and* hypertrophy. This brings me to a much larger gripe, a problem with the fundamental nature of *The Literature*™. The Reader will find many studies in the following paragraphs that include exercises such as the seated knee extension, machine biceps curls, et cetera. These exercises were invented so that mouth-breathers only capable of wiping sweat off of a machine were able to teach paying gym members how to exercise. Any man, woman, or child capable of speaking out loud can learn how to teach somebody what to do on a pec-deck machine. Grab the handles and bring them together. Good. Excellent. Squeeze. Yeah, that's it. That will be $45.

These exercises feature two particularly ugly characteristics. One, they usually isolate a single plane of motion and allow the lifter to forget entirely that we are creatures designed to move in three-dimensional space. The Press is different from a seated machine press for several reasons, but perhaps the biggest one is that the machine only allows the lifter to move vertically. In the Press, especially a dynamic one with a layback, our body does much work in multiple planes throughout the movement.

We press the bar in a straight line, but only if we force ourselves to do so. It is easy, especially in the beginning, to find ourselves in the habit of pressing the bar forward of the mid-foot or even jiggling the bar laterally throughout the motion. We must learn to control the barbell and fix these inefficiencies, one of the key skills in learning barbell exercises. Machines do all of this for us, rendering our ability to move in space as what we in The Biz call "pathetic." The other issue is a byproduct of the isolated movement that forces the lifter into using one, maybe two muscle groups. Usually, the machine is designed to allow total isolation. This is a problem because these movements are entirely contrived and not seen in the Real World.

When Martha Stewart reaches into her cupboards, she does not externally rotate her shoulder joint to place her elbow at her side, then flex her shoulder to bring her arm overhead while maintaining perfect external rotation, then grab a plate, then bring everything back down in the opposite order it went up. (Although, many health experts would say this is exactly how it should happen and that she needs to be mindful of her rotator cuff muscles while she is in the kitchen. Hi, I'm Earth, have we met?) The rotator cuff muscles only perform movement of the shoulder when they are isolated. In Reality, they simply protect the integrity of the shoulder joint while we move normally, keeping the head of the humerus pulled into the glenoid fossa while we throw our arms in the air and wave 'em like we just don't care.

This is merely one example to show the absurdity of dividing the body into individual parts that operate in a vacuum. The low-bar squat is a contrived movement, sure, but it was designed to stress several muscle groups over a long range of motion in the systematic way in which they already operate. A toddler performs perfect squats daily, while never once doing anything that resembles an isolated hip abduction or a seated knee extension. So why do some of the Lab Coats consistently study exercises that force the use of light weight throughout a fixed range of motion and provide a fraction of the strength/hypertrophy benefits of barbell movements? Because they have never lifted weights and they haven't the foggiest idea about how to coach their study subjects through the movements.

My last gripe is with training status. I will note in the following studies whether the subjects included were trained, but how do the experimenters truly know? And, if the lifters are untrained, why bother? What can we tell from studies with subjects whose recent activity included brisk walks from their car to their front door and grocery bag rack pulls? The only value in testing untrained people with training is to see what happens specifically in untrained people. However, we are not untrained, and I would be surprised if any untrained people are interested in the outcome of a RT study. Why would they be? If they were interested in training they would not be untrained and if they were trained they would not be interested in studies with untrained subjects. So, what good is the study outside of the fact that the experimenters earned their degree after the paper was published? My blood pressure is rising.

Moreover, there don't seem to be accepted criteria that define "trained" status across all the studies, and several studies with "trained" lifters do not give a precise definition of what they deem to be trained. It's often that the subjects tell the Lab Coats that they've been exercising regularly for the last three or six months, but what does exercise mean? Have they done the Novice Linear Progression and Texas Method templates? Were they doing CrossFit or Zumba classes? Does physical therapy qualify as lifting? I mean for the Lab Coats, not me. As far as I'm concerned, Physical Therapy is only challenging for corpses.

Anyway, this is why we in The Biz have such a difficult time accepting *The Literature*™ as valid for any interpretation at all. No good coach or lifter in the world does a majority of their strength or hypertrophy training on machines. Furthermore, no bodybuilder in the history of man has based

the majority of his training on high-rep, low-intensity loading, and especially not on machines. My Readers can research this on their own time, but Ronnie Coleman squatted 800 for 2 reps while competing for his Olympias, Arnold was winning European powerlifting competitions in his teens, and Dorian Yates was hitting 405 lb for volume on the incline bench press before he ever competed in bodybuilding. Machines hardly existed in Arnold's time and Coleman didn't get to an 800+ squat with knee extensions. These impressive levels of strength are what laid the groundwork for their ability to perform hundreds of reps per training session later in their bodybuilding careers. One has to earn his volume.

It is obvious that the vast majority of Lab Coats are not lifters, because they would not feel comfortable using a training prescription that so demonstrably neglects barbells and dumbbells. Hypertrophy and strength are grounded in difficult barbell work. They are not achieved through a padded seat with CNN playing on a TV overhead. It is tough to take a lot from a study that believes a machine biceps curl with ~35 lb could achieve similar results for the biceps as chin-ups or heavy barbell rows. This mode of thinking is symptomatic of a grim pathology. Men and women who have not lifted heavy weights for any extended period of time, if ever, are telling the lay public how to get strong and make muscles grow. It would be fine with me if The Reader thought of this behavior as **fraudulent**. Not only have most of them not done any serious strength training themselves, but they have not coached anybody through these processes either. What do they know about training?

These criticisms should foster a deep skepticism in The Reader. We need to mind our step when combing *The Literature*™ because we do not want to encourage these barely sentient Lab Coats to continue offering isolation exercises in place of compound barbell movements, and there is often little practical advice we can take into the weight room from these lame studies. So, how do we read these experiments? *Very carefully.* I will try to mine what I can from all that follows, but be cognizant of the issues inherent in the data that come from such poor methodologies. To be fair, there are a couple of excellent studies that follow. They utilize barbell exercises and adhere quite closely to what would constitute real strength training. Still, it would behoove The Reader to carry a healthy skepticism through this article (and life).

By the end of this post, The Reader will be hit with a summary and some pragmatic guidelines. Spoiler alert: The Reader needs to lift a lot, lift often, and lift heavy. If The Reader is so inclined, he can come along with me as I venture into the voluminous depths of *The Literature*™.

The Important Definitions

Volume: sets multiplied by reps, e.g. 5 sets of 5 reps would be 25 reps of volume. Sometimes volume is referred to more generally as the number of working sets and the reps are ignored.

Volume Load (VL) or Tonnage: resistance multiplied by sets and reps, e.g. 5 sets of 5 reps with 225 lb would be 5625 lb of tonnage or VL.

Cross-Sectional Area (CSA): the area of the cross-section of a muscle perpendicular to its fibers. An accurate way to quantify the size of a muscle.

Repetition Maximum (RM): "rep max" or the maximum amount of weight that can be lifted for a certain number of repetitions. Usually written as 1RM, 5RM, 10RM, etc.

Intensity: the percentage of one's RM, often written as "60%1RM", which would be 60 percent of a lifter's 1RM weight. If a lifter can squat 200 lb for a maximum of 5 reps, 80%5RM would be 160 lb.

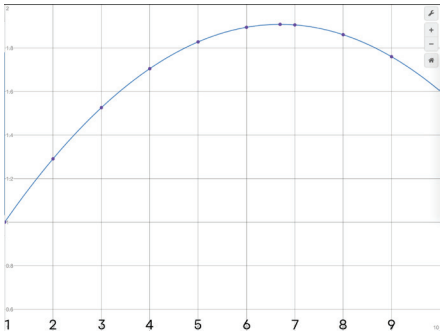
I will provide links to every study and the bibliography will be at the bottom. *Get some coffee*.

VOLUME – Minimum Effective Dose?

In our world of training, the MED would be the smallest possible stress we could undergo in order to induce an adaptation. This is popular, especially with the Tim Ferriss types, as he's built a multi-million-dollar empire on this exact ideology with his *4-Hour Body.* Although, at average height, I think The Reader would rather lift like Dan Green [2] than Tim Ferriss. But, how? What is needed to produce a hypertrophic response from training? While it is certainly possible that an untrained lifter could benefit from doing a single set to volitional failure, how long would that last as a viable stimulus that would produce an adaptation? Is it even possible for a trained person who's been lifting seriously for, say, six-plus months to find a single set to be an overload event? The MED has obvious value, but let us see what the data tell us. All four of these entries were compiled in Schoenfeld and Grgic's [3] work, but they showed:

- 3 sets v. 1 set [4]: 36 **untrained** men performed either 3 sets of leg extensions or one set of leg extensions. While the evidence was not conclusive, the first group's thigh cross-sectional area grew 6.8 percent v. the second group's 3.1 percent. Not statistically significant but practically so, as the group utilizing multiple sets had a 119 percent greater hypertrophic response. We would expect a large cohort of untrained men to respond to a new training stimulus no matter what it is since almost anything will disrupt homeostasis. However, even in untrained men, 3 sets appeared more valuable than just one.
- 4 v. 2 v. 1 [5]: 3 groups of resistance-**trained** men did 1, 2, or 4 sets of leg extensions and growth in the cross-sectional area of the quadriceps hit 6.3, 4.6, and 12.3 percent, respectively. Again, while not statistically significant, still meaningful for us. One set and two sets seemed hardly different, even a bit of a drop in the average response for the latter group, but the group who did 4 sets saw 95 percent more growth than the first group.
- More is better [6]: 8 total studies were included in a meta-analysis done by Krieger to understand whether a single set or multiple sets is more beneficial to hypertrophy. Across the board, multiple sets were better. I feel shocked [7].
- More is better, 10-plus [8]: 15 studies were included in a meta-analysis to look at the number of sets performed per muscle group per week (<5, 5-9, 10+) and they found that more is better. The gains in hypertrophy were 5.4, 6.6, and 9.8 percent, respectively.

Let me dig into the aforementioned meta-analysis of eight studies done by Krieger [6]. He found a 40 percent increase in hypertrophic effect sizes in the studies when multiple sets (2-3) were compared with single sets. Moreover, the effect sizes grew again when 4-6 sets were studied. If I were to borrow a mathematical idea [9] from Mr. Science, Greg Nuckols, and calculate a parabolic line of best fit for the effect sizes, we would be able to visualize a unitless "hypertrophic effect" (y-axis) per set (x-axis) – essentially, how valuable each consecutive set is to



We can see a clear point of diminishing returns at just under 7 sets for these trained lifters. Equation: y = 7/250x^2 + 3/8x + 653/1000. Graphing tool: Desmos.

our Gains. In addition, it will provide us with an idea of where a point of diminishing returns may pop into the equation for lifters. All of this would obviously be largely dependent on training history and efficacy, but it's a good illustration to get the noggin' joggin'.

Krieger's [6] work would also jibe with the meta-analysis done by Peterson et al. [10], as they combined a staggering 177 studies with 1,803 effect sizes to understand how **untrained lifters**, **recreationally-trained lifters**, and **athletes** responded to training volume for strength gains.

In the work of Peterson et al. we see that upwards of 8 or more sets per training session can be required for an athlete, somebody with an extensive training history, to maximize strength gains. In untrained folks, as low as 60 percent of 1RM can be used with only 4 working sets to maximize strength 3 days per week, but it has been thoroughly discussed before why it is impossible to get an accurate 1RM in untrained lifters, as they do not yet possess the neuromuscular efficiency or skill to perform the task of a maximum-effort lift, and they can get stronger every time they train for several consecutive weeks. Untrained lifters are sent to the Blue Book, *Starting Strength: Basic Barbell Training*. Recreationally-trained lifters responded best to a mean training intensity of 80%1RM with 4 sets, only 2 days per week. Athletes, on the other hand, needed a mean of 8 sets per muscle group twice per week to maximize strength gains. So, there exists a strong correlation between increasing volume and maximizing hypertrophic gains, but also for maximizing strength gains.

Since we thoroughly understand Homo sapiens and his tendency to wither and die from too much stress, we can intuit that an upper threshold of training volume must exist. We will hit a point of diminishing returns where the effort-to-benefit ratio begins to deteriorate drastically. That is known in The Biz as a "waste of time." Soon after that, we would hit a point at which increasing volume any further would result in a detriment to our training, e.g. crippling soreness, increased risk of injury, unhelpful fatigue, bad taste in music, etc.

One study by Amirthalingam et al. [23] tested German Volume Training (GVT), often called the 10-set method, against a more typical hypertrophy program involving 5 sets. The men involved were **trained** with at least one year of experience. Instead of typing it all out for The Reader, the two protocols were:

Resistance Training Protocol								
Session 1								
Exercise	Load	Sets x Reps	Exercise	Load	Sets x Reps	Exercise	Load	Sets x Reps
Flat Bench Press	60%1RM	10 or 5 x 10	Leg Press	80%1RM	10 or 5 x 10	Shoulder Press	60%1RM	10 or 5 x 10
Lat pull-down	60%1RM	10 or 5 x 10	Dumbbell Lunges	70%1RM	10 or 5 x 10	Upright Row	60%1RM	10 or 5 x 10
Incline bench press	70%1RM	4 x 10	Leg Extensions	70%1RM	4 x 10	Tricep Push-downs	70%1RM	4 x 10
Seated Row	70%1RM	4 x 10	Leg Curls	70%1RM	4 x 10	Biceps 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

As we can see, the first two exercises were either a GVT prescription of 10 sets of 10 reps (that's going to be a yikes for me, dawg) or 5 sets of 10 reps. Both groups, however, performed assistance work and at the same intensity/volume. This was done to comply further with the philosophy of the split routine implemented by most bodybuilding/hypertrophy-focused lifters.

The 5-set group gained 71 percent more total body mass and 42 percent lean body mass (LBM) over the GVT group. Lean tissue growth in the arms and trunk favored the 5-set group as well, though not significantly. The 5-set group saw a 72% greater increase in 1RM leg press strength, a 140% greater increase in 1RM bench strength, and a 236% greater increase in 1RM lat pull-down strength. The only GVT-favored outcome was muscle thickness in the triceps. This gives us a clear warning about the potential for 31 working sets per muscle group versus 21 working sets per muscle group per week. There is an obvious point of diminishing returns, although an increase in strength and

LBM was still observed in the GVT group, so they certainly were not regressing. However, it's unclear how long they would be able to withstand this level of volume before the Reaper caught up with them.

The data show, despite the recurring use of leg extensions, that the Minimum Effective Dose has Minimum Effective Value unless the lifter pays attention to the Minimum Effective Volume. While there is importance in individual variation in ability to handle a given workload, it is clear that we need more stress, and specifically, more volume rather than less. We especially need more volume if we are looking to maximize hypertrophy, and the battle against Father Time is always an uphill fight (unless The Reader is LeBron James. If he is LeBron, contact me so we can fix that hideous squat form [12], I will fly to LA yesterday.). As we make more progress, Gains become more marginal and we will have to turn over every stone in order to keep moving forward. More sets give greater benefits than fewer sets, but how many repetitions should we use?

Repetition Range

In this study by Morton et al. [13], we see 49 **trained** young men perform full-body workouts 3 times per week for 12 weeks using either 30-50%1RM for 20-25 reps per set or 75-90%1RM for 8-12 reps per set. There were no significant differences in increase between the groups in acute changes in systemic hormone concentrations, skeletal muscle biopsies, strength testing, and dual-energy X-ray absorptiometry scans. The only significant difference was in bench press strength, the group with the high-load, low-ish-rep prescription improved significantly more (HR, 9 ± 1, vs. LR, 14 ± 1 kg, P = 0.012). An aside: a lifter cannot perform 8-12 reps with 90%1RM, so these Lab Coats did not get accurate test results (90%1RM is a fairly heavy single and close to a 3RM effort). Way off.

In this study by Campos et al. [14], 4 groups of **untrained** men went through an 8-week training protocol. Group One (Low Rep, n=9) performed 3 to 5 reps for 4 sets of each exercise with 3-minute rest intervals. Group Two (Int. Rep, n=11) performed 9-11RM for 3 sets with 2-minute rest intervals. Group Three (High Rep, n=7) performed 20-28RM for 2 sets with 1-minute rest intervals. The fourth group was a non-exercising control (Con, n=5). Three exercises (leg press, squat, and knee extension) were performed 2 days per week for the first 4 weeks and 3 days per week for the final 4 weeks.

"Maximal strength improved significantly more for the Low Rep group compared to the other training groups, and the maximal number of repetitions at 60%1RM improved the most for the High Rep group." This is not a surprise, as merely practicing 20-28RM consistently would make one better at performing high-rep maximal sets. We also know that strength adaptations become more specific the longer we train and there are skills involved in performing a 1RM that one does not get if they consistently train in moderate- to high-rep schemes. The reverse is true for high-rep max sets and training in low-rep schemes, although a strong man gets better at high-rep sets by accident because heavier weights become more submaximal as he gets stronger. The reverse is not true for high-rep training.

"All three major fiber types (types I, IIA, and IIB) hypertrophied for the Low Rep and Int Rep groups, whereas no significant increases were demonstrated for either the High Rep or Con groups." This is actually quite surprising. For a group of untrained men, the High-Rep prescription should have forced some form of growth because untrained subjects usually grow *no matter what they do*; this is the nature of going from untrained to trained. However, the high-rep scheme proved antithetical to hypertrophic gains in this case. Perhaps this is why running a marathon, or as I like to call it, a 55,000RM, doesn't seem to result in anything but catabolism.

A study by Klemp et al. [15]tested two groups of **trained** men with two nearly equal volume prescriptions for daily undulating periodization strategies over 8 weeks. The first group (DUPHR, n=8) performed 4x12 at 60%1RM on day one, 4x10 at 65%1RM on day two, and 5x8 at 70%1RM on day three for the squat and bench press exercises only. The second group (DUPLR, n=8) performed 8x6 at 75%1RM on day 1, 9x4 at 80%1RM on day 2, and 10x2 at 85%1RM on day 3 for the same 2 exercises.

Does The Reader notice how they performed doubles at 85%1RM but the first study in this section claimed 8-12 reps at 90%1RM? The Lab Coats must be held accountable for their ignorance. This is a much better study.

DUPHR, the high-rep group, performed 128 working reps of volume against DUPLR's 104 reps. However, DUPLR, the low-rep group, had a 15.24 percent average increase in pec cross-sectional area (CSA), and 11.23 percent average increase in quad CSA. DUPHR had a 12.72 percent average increase in pec CSA and 11.15 percent average increase in quad CSA. There was not a significant increase in hypertrophy from performing higher reps and the results slightly favored the DUPLR group.

Lastly, let us understand the meta-analysis by Schoenfeld et al. [16] on *Strength and Hypertrophy Adaptations Between Low- Vs. High-Load Resistance Training.* They found 21 studies that met their criteria and concluded that the spectrum of high-load (low-rep) down to low-load (high-rep) provided similar hypertrophic effects, but the results slightly favored high-loads. Far from statistically significant, they were unable to say one is more beneficial than the other. They were, unsurprisingly, able to definitively call high-load training significantly more beneficial for strength gains, particularly 1RM performances.

Moreover, they found a tendency for load-specific outcomes in muscle fiber growth. The higher the load the more type II fibers grow and the lower the load the more type I fibers grow. This is not a shocking discovery, as we know this about the fibers:

	Type I fibers	Type IIa fibers	Type IIx fibers	Type IIb fibers
Contraction Time	Slow	Moderately Fast	Fast	Very fast
Size of motor neuron	Small	Medium	Large	Very large
Fatigue resistance	High	Fairly high	Intermediate	Low
Activity	Aerobic	Long-term anaerobic	Short-term anaerobic	Short-term anaerobic
Max duration	Hours	<30 minutes	<5 minutes	<1 minute
Power	Low	Medium	High	Very high
Mitochondrial density	High	High	Medium	Low
Capillary density	High	Intermediate	Low	Low
Oxidative capacity	High	High	Intermediate	Low
Glycolytic capacity	Low	High	High	High
Major storage fuel	Triglycerides	PCr, glycogen	PCr, glycogen	PCr, glycogen
Human genes	MYH7	MYH2	MYH1	MYH4

I'm not much for bedazzling.

Since we know this about muscle fibers, it would follow that strength training, particularly short, heavy strength training, would predominantly require the use of type II fibers. The opposite would, therefore, be true for slow, lighter strength training that is to be endured for up to several minutes per set. To best Grow Large and take up all the space in the booth at Applebee's, rep schemes of all flavors

should find a spot in the lifter's training. However, since type II fibers are the biggest and baddest [17], training should still center around high-loads.

If high repetitions, 15 or more, require us to take plates off the bar and sacrifice strength gains, but low-to-moderate repetitions, 1-12, allow us to get mightily strong and influence hypertrophy as much as the former, why should we spend a considerable amount of time with high reps? It seems to me that we shall only look north of 15 when we really want *The Pump*™ or happen to remember that we have type I muscle fibers. Well, now we know how many reps we need to fall in love with, but is failure better than a volitional finish to a set? The short answer is no, but I am not one for such a brief response.

Failure vs. Volitional Sets

This study by Nobrega et al. [18]showed in 32 **untrained** men that high-intensity and low-intensity sets done not to failure but stopped volitionally had the same effect on muscle mass, strength, and pennation angle as high and low-intensity sets done to failure. This could imply that sets taken to failure are not necessarily more beneficial to sets ended with a rep or two left in the tank.

A study by Sampson and Groeller [19] assessed a more specific response in **untrained** men, as they tested non-failure rapid shortening (RS: 2s eccentric, rapid concentric), non-failure stretch-shortening (SSC: rapid eccentric, rapid concentric), and failure control (C: 2s eccentric, 2s concentric) 3 times per week with 85%1RM in 28 men. They were studying 1RM, maximal voluntary contraction (MVC), muscle cross-sectional area (CSA), and muscle activation (EMG(RMS)) of the agonist (prime movers), antagonist (opposing muscles), and stabilizer muscles before and after the 12-week program.

The average number of reps performed in RS was 4.1, SSC was 4.2, and C was 6.1, so it appears the group working to failure underwent more volume on average. Every parameter (MVC, CSA, EMG) improved, but no significant difference was detected among the groups, implying that lifting to failure doesn't provide any significant evidence for better hypertrophic outcomes, even if the volume was slightly higher.

For what it's worth, this study by Prestes et al. [20] suggests that Rest-Pause sets showed a significant increase in thigh hypertrophy and localized muscle endurance in the leg press over traditional multiple sets with a normal rest interval in this case. The muscle endurance improvement would imply that *practicing reps with very little rest* made the subjects better at *performing reps with little or no rest*, which would certainly comply with the Specificity of Adaptation to Imposed Demand (SAID) Principle, and the one I just made up, called the Duh Principle. I think this rest-pause training strategy may be useful to employ every now and then, perhaps during relatively low-stress volume work at the end of a session. My tactic of choice for volume that follows a Rest-Pause prescription are Myo-Reps [21].

While we are on the subject of strange reps, a study done by Masahiro et al. [22] showed that a partial range of motion (ROM) program showed significantly better hypertrophic responses from an increase in intramuscular hypoxia than a full ROM program. This suggests that partial ROM training and exercises should hold a place in our training. Block benches, rack pulls, halting deadlifts, that kind of thing. We already know they are excellent for building strength, but they seem to also be quite beneficial for hypertrophy.

Anyway, many of the studies listed in these paragraphs utilize failure because of the subjectivity involved in stopping a set volitionally. This renders it somewhat difficult to find many studies that directly pit failure against a volitional end, but the couple cited above give us an idea that failure does

not seem to represent any unique characteristics that the latter does not. To me, failure is a great way to accumulate unnecessary fatigue, increase our risk of injury (especially in barbell exercises and heavy compound movements), and require the regular use of a spotter. Some of us don't have any friends to goad into holding our elbows while we press dumbbells. We have to use the old-fashioned method of safety: prayer.

Now we know that we need *many working sets of volume per week*, at least 10 per movement/muscle group, and we also know that we need to cycle our rep schemes throughout the 1-12 range. But wait, how long should we rest between sets? The bodybuilders might get upset with me over this one, but if they take three deep breaths and make an attempt at objectivity they will find the next segment to be good news.

Rest Intervals

A study by Schoenfeld et al. [23] tested twenty-one **trained** male volunteers for 1RM in the bench press and back squat, muscle endurance at 50 percent of 1RM to failure, and muscle thickness of the elbow flexors, triceps brachii, and quadriceps femoris. Both groups were prescribed 3 sets of 12 reps for 7 exercises for 3 full-body workouts per week. The only difference was one group (SHORT - 11 subjects) was allowed a 1-minute rest interval while the other group (LONG - 10 subjects) was allowed 3-minute rest intervals. As expected, the 1RM tests for the bench press and back squat showed significantly more improvement in the LONG group than in SHORT. However, contrary to what we have been brainwashed to expect (I have tinfoil wrapped around my head), the LONG group showed greater hypertrophic responses as well. The increase in anterior thigh CSA was significantly better in the LONG group, and the triceps brachii improvements were trending in the same direction. The difference in biceps brachii CSA increases did not show statistical significance, but the effect size suggests that the LONG group's biceps responded more than the SHORT group's (0.39 and 0.18, respectively) and may have shown a bigger discrepancy had the study continued for several more weeks.

This study by Buresh et al. [24] tested twelve **untrained** males for changes in hormone response, strength, arm cross-sectional area (CSA), thigh muscular cross-sectional area (MCSA), and body composition during a 10-week training period and used either one or 2.5 minutes of rest between sets. The long-rest group saw a significantly greater increase in arm CSA over the short-rest group. This is likely due to the fact that the long-rest group was able to perform many more repetitions per set, on average, than the short-rest group. The 1-minute rest interval elicited a greater hormonal effect than the 2.5-minute interval, but this vanished by week 5. This means that as the lifter became more *trained*, the hormonal effects, assumed to increase anabolism and hypertrophic outcomes, were not significantly different. We'll get to hormonal effects and anabolism later.

Another study, this one by Ahtiainen et al. [25], took 2 groups of **trained** men through 6 months of training to test basal hormonal concentrations of serum total testosterone (T), free testosterone (FT), and cortisol (C), maximal isometric strength of the leg extensors, right leg 1RM, dietary analysis, and muscle cross-sectional area (CSA) of the quadriceps femoris by magnetic resonance imaging (MRI) were measured at months zero, 3, and 6. The first group (LONG - 5-minute rest intervals) was compared to the second group (SHORT - 2-minute rest intervals) in order to see the effects of longer rest intervals. They found very little. The LONG group used higher intensities so they trained with heavier weights consistently, but the muscle size, hormone levels, and strength performances improved to a virtually identical degree.

I think the big takeaway from this is, as in our previous study, resting only 1 minute is far from ideal. We would be wise to utilize rest intervals between 2 and 5 minutes. This is obviously a big range, but let me talk through it. If a 4- or 5-minute rest interval would allow us to recover more than a 2-minute interval, it would follow that we would be able to safely execute more reps and increase our volume and tonnage for each exercise and workout. This would result in, especially over several months of training, a vast improvement in accumulated training workload. Furthermore, if the 2-minute interval does not improve our workout in any tangible metric outside of *The Pump*™, why would we shortchange our improvements in strength, volume, and work capacity by doing less work?

A meta-analysis from de Salles et al. [26] looked at the relationship between inter-set rest intervals and training outcomes in 35 studies. The acute effects are exactly what I talked through in the last paragraph.

Study	Load	Exercises and intervals		Set 1	Set 2	Set 3	Set 4	Set 5
Kraemer	**10RM**	**Bench press + leg press**						
		1 min		10	8	7.1		
		3 min		10	10	10		
Richmond and Godard	**75%1RM**	**Bench press**						
		1 min		11.9	6			
		3 min		11.5	8			
		5 min		11.5	10			
Willardson and Burkett	**8RM**	**Bench press**						
		1 min		7.4	4.4	2.8	2.4	
		2 min		7.7	5.7	4.2	3.9	
		5 min		7.6	6.5	6	5.6	
		Squat						
		1 min		7.8	5.9	4.4	4.2	
		3 min		8	6.6	6	4.8	
		5 min		8	7.8	7	6	
Willardson and Burkett	**80%1RM**	**Bench press**						
	50%1RM	1 min	80%	9.3	3.3	2	1.6	1.6
		1 min	50%	29.8	10	7	6.1	6
		2 min	80%	9.1	5.1	3.3	2.8	2.5
		2 min	50%	29.9	14.8	11.1	9.7	9.1
		3 min	80%	9.1	5.9	4.6	3.8	3.5
		3 min	50%	30.4	18.2	14	12.6	12.2
Willardson and Burkett	**15RM**	**Bench press**						
		30 sec		14.9	4.9	2.4	1.8	1.5
		1 min		14.6	5.9	3.6	3.3	2.8
		2 min		14.6	8.6	5.6	5.3	4.9
		Squat						
		30 sec		15.6	10.1	6.8	5.9	5.4
		1 min		15.4	10.6	8.4	6.2	6.3
		2 min		15.4	12.5	10.6	9.4	8.6

Believe it or not, I've actually read *The Visual Display of Quantitative Information*.

As I predicted (because my IQ is above 30), the longer the lifter rested the more reps, on average, he was able to execute throughout each study. The Reader can get out a sheet of paper and check my math, but I'm quite sure of the fact that when a bigger number is added to a bigger number it creates a bigger sum of the numbers than if the numbers added were smaller. (For the record, my IQ

is somewhere between Mike Tyson's and John von Neumann's.) Even at the low intensities, 50%1RM, there was a massive difference between 1, 2, and 3-minute rest intervals.

For Willardson and Burkett's second study above, I'm going to plug in 200 lb as the mean bench press 1RM for the subjects. This will illustrate the amount of work we are missing if we utilize short rest intervals. The numbered list represents the duration of the rest interval. The volume and tonnage were:

1. 80% (17.8 reps for 2848 lb) – 50% (58.9 reps for 5890 lb)
2. 80% (22.8 reps for 3648 lb) – 50% (74.6 reps for 7460 lb)
3. 80% (26.9 reps for 4304 lb) – 50% (87.4 reps for 8740 lb)

When the lifter went from a 1- to 2-minute rest interval, they gained 28 and 27 percent on volume and tonnage at the 80 and 50 percent intensities, respectively. When they went from a 2 to 3-minute rest interval, each improved by another 18 and 17 percent, respectively. When the lifters took 3-minute rest intervals instead of 1, they increased their volume and tonnage 51 percent at the 80%1RM intensity and 48 percent at the 50%1RM intensity. This is far from trivial. Even if we are under the impression that shorter rest intervals are better for hypertrophy because of *The Pump*™, we cannot ignore the discrepancy between the total volume/work we can accumulate with longer rest intervals versus the short intervals. The Reader can re-read the first segment on volume if he forgets the importance.

In this Holy Grail of a meta-analysis, Henselmans and Schoenfeld [27] looked at every study that "examined the relationship between inter-set rest intervals and muscle hypertrophy or a mechanism underlying or mediating this relationship" in order to decipher whether there is merit in implementing short rest intervals, the ones usually promoted as superior for hypertrophic Gains, over longer rest intervals, the ones usually promoted as superior for strength Gains. In short, they concluded, "to date, no study has demonstrated greater muscle hypertrophy using shorter compared with longer rest intervals."

I'll go out on a limb and assume The Reader may need more convincing on this topic. I will quote (and add emphasis where I please) their efficient use of the English language from the abstract:

> "Rest intervals less than 1 minute can result in acute increases in serum growth hormone levels and these rest intervals also decrease the serum testosterone to cortisol ratio. Long-term adaptations may abate the post-exercise endocrinological response *and the relationship between the transient change in hormonal production and chronic muscular hypertrophy is highly contentious and appears to be weak.* The relationship between the rest interval-mediated effect on immune system response, muscle damage, metabolic stress, or energy production capacity and muscle hypertrophy is still ambiguous and largely theoretical. *In conclusion, the literature* ***does not support the hypothesis that training for muscle hypertrophy requires shorter rest intervals than training for strength development*** *or that predetermined rest intervals are preferable to auto-regulated rest periods in this regard.*"

They add in the conclusion, "previous recommendations to employ 0.5- to 1-min rest intervals in resistance training programs designed to maximally stimulate muscle hypertrophy mediated by an elevation in post-exercise serum growth hormone levels have become scientifically untenable." Bring on the controversy. I live for this.

"Longitudinal studies that directly measured hypertrophy in groups with various rest intervals found either no differences between groups or, in the study by Buresh et al., a higher increase in muscle girth in the group using 2.5-min rest intervals than in the group using 1-min rest intervals."

The Reader already knows about this study, as I covered it in a bit more detail above. When that data is understood in its entirety, it's clear that *trained* subjects would not experience those differences in muscle growth.

A message to all of the fitness experts who say *"try THIS rest interval for UNREAL TESTOSTERONE production!"*: "The decrease in testosterone to cortisol ratio associated with rest intervals shorter than 2 minutes may be detrimental to muscle growth, but this remains a theoretical concern in the absence of empirical support. Other hormone levels seem to generally be unaffected by the manipulation of inter-set rest periods." Essentially, there is absolutely no evidence that shorter rest intervals provide any significant endocrinological effects.

In regards to the metabolic stress and cell swelling that is associated with shorter rest intervals and *The Pump*™, "there is currently no direct empirical evidence to support the hypothesis that shortening inter-set rest periods will benefit chronic muscle hypertrophy as a result of increased metabolic stress." Moreover, "rest interval length does not seem to be associated with markers of muscle damage, with the exception of an increase in individuals with a high serum [creatine kinase] response to resistance training. In these individuals, the extraordinary increase in muscle damage may impair muscle hypertrophy."

In summary, "more generally, the literature as a whole suggests that rest interval manipulation has minor effects on muscle hypertrophy compared with other training parameters such as work volume, which suffers when inter-set rest is insufficient even in trainees accustomed to this type of training." Didn't I say this a couple minutes ago? I still wish I weren't right all the time. Volume and intensity are still the most important factors when it comes to hypertrophy. If we want to be muscular, we need to improve our total work capacity, slowly but efficiently. Longer rest intervals give us a much better shot at performing higher volume with more weight which skews our training toward higher levels of tonnage over time which will lend itself to a greater work capacity.

With even a modicum of impartiality, it becomes obvious that we should ditch the idea that short rest intervals are preferable to long for hypertrophic training outcomes. Perhaps, PERHAPS, just maybe it is possible that the short rest interval dogma is merely tradition that has been handed down through the generations, as the bodybuilding community has historically been, let's say, *forgetful* when asked to provide a citation for a given belief. Given the obvious benefits in strength and accumulated volume and/or tonnage that come from longer rest intervals, why would we not center our training around relatively high-intensity sets with 2-plus minutes of rest? Okay, so we need much volume in the 1-12 rep range with rest intervals north of 2 minutes, with auto-regulation being our best tool, but what does The Literature™ say about tonnage and its link to hypertrophy? Well, not a lot.

To be continued in Part 2...

References

1. Schoenfeld, B., Contreras, B., Vigotsky, A., Peterson, M. (2016). Differential Effects of Heavy Versus Moderate Loads on Measures of Strength and Hypertrophy in Resistance-Trained Men. Journal of Sports Science & Medicine. 15. 715-722.

2. Dan Green - https://www.youtube.com/watch?v=dJE8CdstUg8

3. Schoenfeld, B., & Grgic, J. (2017). Evidence-Based Guidelines for Resistance Training Volume to Maximize Muscle Hypertrophy. Strength and Conditioning Journal, 1. doi:10.1519/ssc.0000000000000363
4. Mitchell, C. J., Churchward-Venne, T. A., West, D. W., Burd, N. A., Breen, L., Baker, S. K., & Phillips, S. M. (2012). Resistance exercise load does not determine training-mediated hypertrophic gains in young men. Journal of Applied Physiology, 113(1), 71-77. doi:10.1152/japplphysiol.00307.2012
5. Ostrowski, K. J., Wilson, G. J., Weatherby, R., Murphy, P. W., & Lyttle, A. D. (1997). The Effect of Weight Training Volume on Hormonal Output and Muscular Size and Function. Journal of Strength and Conditioning Research, 11(3), 148-154. doi:10.1519/00124278-199708000-00003
6. Krieger, J. W. (2010). Single vs. Multiple Sets of Resistance Exercise for Muscle Hypertrophy: A Meta-Analysis. Journal of Strength and Conditioning Research, 24(4), 1150-1159. doi:10.1519/jsc.0b013e3181d4d436
7. Pepper Brooks - https://www.youtube.com/watch?v=uLr0v9MyGgM
8. Schoenfeld, B. J., Ogborn, D., & Krieger, J. W. (2016). Dose-response relationship between weekly resistance training volume and increases in muscle mass: A systematic review and meta-analysis. Journal of Sports Sciences, 35(11), 1073-1082. doi:10.1080/02640414.2016.1210197
9. Greg Nuckols - https://www.strongerbyscience.com/hypertrophy-range-stats-adjustments/
10. Peterson, M. D., Rhea, M. R., & Alvar, B. A. (2005). Applications of the Dose-Response for Muscular Strength Development: A Review of Meta-Analytic Efficacy and Reliability for Designing Training Prescription. The Journal of Strength and Conditioning Research, 19(4), 950. doi:10.1519/r-16874.1
11. Amirthalingam, T., Mavros, Y., Wilson, G. C., Clarke, J. L., Mitchell, L., & Hackett, D. A. (2017). Effects of a Modified German Volume Training Program on Muscular Hypertrophy and Strength. Journal of Strength and Conditioning Research, 31(11), 3109-3119. doi:10.1519/jsc.0000000000001747
12. LeBron James - https://www.youtube.com/watch?v=ZvgkdHOG50E
13. Morton, R. W., Oikawa, S. Y., Wavell, C. G., Mazara, N., Mcglory, C., Quadrilatero, J., . . . Phillips, S. M. (2016). Neither load nor systemic hormones determine resistance training-mediated hypertrophy or strength gains in resistance-trained young men. Journal of Applied Physiology,121(1), 129-138. doi:10.1152/japplphysiol.00154.2016
14. Campos, G., Luecke, T., Wendeln, H., Toma, K., Hagerman, F., Murray, T., . . . Staron, R. (2002). Muscular adaptations in response to three different resistance-training regimens: Specificity of repetition maximum training zones. European Journal of Applied Physiology, 88(1-2), 50-60. doi:10.1007/s00421-002-0681-6
15. Klemp, A., Dolan, C., Quiles, J. M., Blanco, R., Zoeller, R. F., Graves, B. S., & Zourdos, M. C. (2016). Volume-equated high- and low-repetition daily undulating programming strategies produce similar hypertrophy and strength adaptations. Applied Physiology, Nutrition, and Metabolism,41(7), 699-705. doi:10.1139/apnm-2015-0707
16. Schoenfeld, B. J., Grgic, J., Ogborn, D., & Krieger, J. W. (2017). Strength and Hypertrophy Adaptations Between Low- vs. High-Load Resistance Training. Journal of Strength and Conditioning Research, 31(12), 3508-3523. doi:10.1519/jsc.0000000000002200
17. Wessel, T. V., Haan, A. D., Laarse, W. J., & Jaspers, R. T. (2010). The muscle fiber type–fiber size paradox: Hypertrophy or oxidative metabolism? European Journal of Applied Physiology, 110(4), 665-694. doi:10.1007/s00421-010-1545-0
18. Nóbrega, S. R., Ugrinowitsch, C., Pintanel, L., Barcelos, C., & Libardi, C. A. (2018). Effect of Resistance Training to Muscle Failure vs. Volitional Interruption at High- and Low-Intensities on Muscle Mass and Strength. Journal of Strength and Conditioning Research, 32(1), 162-169. doi:10.1519/jsc.0000000000001787
19. Sampson, J. A., & Groeller, H. (2015). Is repetition failure critical for the development of muscle hypertrophy and strength? Scandinavian Journal of Medicine & Science in Sports, 26(4), 375-383. doi:10.1111/sms.12445
20. Prestes, J., Tibana, R. A., Sousa, E. D., Nascimento, D. D., Rocha, P. D., Camarço, N. F., . . . Willardson, J. M. (2017). Strength And Muscular Adaptations Following 6 Weeks Of Rest-Pause Versus Traditional Multiple-Sets Resistance Training In Trained Subjects. Journal of Strength and Conditioning Research, 1. doi:10.1519/jsc.0000000000001923
21. RTS Myo-reps - https://www.youtube.com/watch?v=gAy5xLUjha0

22. Goto, M., Hamaoka, T., Maeda, C., Hirayama, T., Nirengi, S., Kurosawa, Y., . . . Terada, S. (2017). Partial range of motion exercise is effective for facilitating muscle hypertrophy and function via sustained intramuscular hypoxia in young trained men. Journal of Strength and Conditioning Research, 1. doi:10.1519/jsc.0000000000002051

23. Schoenfeld, B. J., Pope, Z. K., Benik, F. M., Hester, G. M., Sellers, J., Nooner, J. L., . . . Krieger, J. W. (2016). Longer Interset Rest Periods Enhance Muscle Strength and Hypertrophy in Resistance-Trained Men. Journal of Strength and Conditioning Research, 30(7), 1805-1812. doi:10.1519/jsc.0000000000001272

24. Buresh, R., Berg, K., & French, J. (2009). The Effect of Resistive Exercise Rest Interval on Hormonal Response, Strength, and Hypertrophy With Training. Journal of Strength and Conditioning Research, 23(1), 62-71. doi:10.1519/jsc.0b013e318185f14a

25. Ahtiainen, J. P., Pakarinen, A., Alen, M., Kraemer, W. J., & Häkkinen, K. (2005). Short vs. Long Rest Period Between the Sets in Hypertrophic Resistance Training: Influence on Muscle Strength, Size, and Hormonal Adaptations in Trained Men. The Journal of Strength and Conditioning Research,19(3), 572. doi:10.1519/15604.1

26. Salles, B. F., Simão, R., Miranda, F., Novaes, J. D., Lemos, A., & Willardson, J. M. (2009). Rest Interval between Sets in Strength Training. Sports Medicine, 39(9), 765-777. doi:10.2165/11315230-000000000-00000

27. Henselmans, M., & Schoenfeld, B. J. (2014). The Effect of Inter-Set Rest Intervals on Resistance Exercise-Induced Muscle Hypertrophy. Sports Medicine, 44(12), 1635-1643. doi:10.1007/s40279-014-0228-0

28. *To be continued...*