H. I. T.

Higher Intelligence Training

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The information in this manual is intended only for healthy men and women. People with health problems should not follow the suggestions without a physician's approval. Before beginning any exercise or dietary program, always consult with your doctor.

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Preface

Anyone who is serious about exercise is well aware of the concept of "High Intensity Training," whether practiced or not. Although this methodology of exercise application has been around for about a century, it gained its greatest popularity and clarity because of Arthur Jones' promotion and writings, in the early 1970s. The history of this training direction is explored within this book, but suffice it to say that it has experienced a backlash since Jones' time for political reasons, more so than reasons of science or rationality.

As a result, the few arguments that exist continue to remain vague, and are made public infrequently since anyone with an iota of intelligence can see past the arguments for what they are – naive and groundless self-serving dribble. "More champs train differently," and "it is hard on the body to train like that" is about as good as it gets. Consequently, it is best to keep high intensity training under wraps, as suggested by the lighthearted graphic at the front of this book, "Top Secret." After all, since high intensity training is alive and well, and exists among at least half the NFL teams alone, it is best to ignore than to ridicule, since the latter merely exposes the frailty of the popular 'high volume' methods implemented by genetic anomalies on drugs, and also gives more exposure and credence to high intensity philosophy since even bad press becomes good press and awareness.

Moreover, it is usual for strength training and bodybuilding fitness enthusiasts eventually to discover and embrace brief, intense exercise methods. Those who abandon HIT, in the hopes to discover the 'unknown of body transformation' eventually return. And those who encounter HIT cannot believe how much time they wasted beforehand. This is true since HIT works and because the less intense, higher volume activities supported by fitness magazines cannot deliver what was promised; particularly in regard to the disproportionate cost-benefit of magazine programs and if the trainee is not one of those genetic anomalies on drugs.

Those familiar with high intensity training may not find anything new within these pages, although I hope a few morsels will be discovered. Rather, the purpose of this book is to pull together historical facts, general knowledge, and the most effective applications of high intensity training. Experienced HIT enthusiasts, particularly fitness professionals also may find this book a good education resource or tool for clients or for conducting lectures, particularly when compared to the so-called 'high intensity' learning resources offered through certification organizations that neither endorse nor believe in this exercise direction. Apparently they include single edition books in their repertoire for commercial and financial reasons.

Chapter 1

History and Philosophy of High-Intensity Training

The concept of ‘high intensity training’ (HIT) has an extensive and somewhat negative history, which is ironic since it initially was promoted as follows:

1. Use proper form
2. Train as hard as possible
3. Allow enough time between sessions to recover, so that growth/strength can increase.

Certainly such advice would be expected in any exercise program that desires optimum results. However, since this direction in exercise happened to coincide with the promotion of Nautilus machines and denounced the use of protein supplements, the industry (i.e., the muscle magazines that promoted otherwise) was up in arms.

Discussed in a later chapter will be the positive outcomes of proper high intensity training, but at this point it is important to look at the history of high-intensity exercise, as well as discuss why this training method is looked down upon by much of the industry, and even some of the dogmatic biases of HIT-supporters.

High Intensity Strength Training – A Brief History*

The pure objective of exercise is the scientific study of physiological change. In twofold, we first must prevent the change characterized as a loss of function (negative) and do whatever possible to promote it an increase in function (positive). How the progress of change occurs is open to debate, but such change is undeniable. Those not being satisfied with what they have will strive for continued improvement. They will try anything suggested from the so-called experts, without actively pursuing the pure understanding of the rationale of cause and effect. Their choices, of course, will go in the direction of doing much more exercise than is required. This direction has always been the most popular and vastly proposed way to do it, or "Just Do It."

However, in spite of this, intelligent observations suggest that muscular growth is induced from a measurably intense to an extremely highly intense training stimulus to the muscular structures. Such a program requires a brief bout of an eventual advanced level of exercise, and that being contrary to the trendy belief of just doing more sets or cycles. Follow the logic in this legendary statement: "I think it is most important to discover as quickly as possible in your physical culture career not how much exercise is necessary, but how little," Harry Paschall, circa 1950. One will be much closer to the truth by following such rationale. Arthur Jones founder of the Original Nautilus Sports Medical Industries and the MedX Corporation, often repeats this manifesto to this very day; a statement that has taken its fair share of indiscriminate criticism.

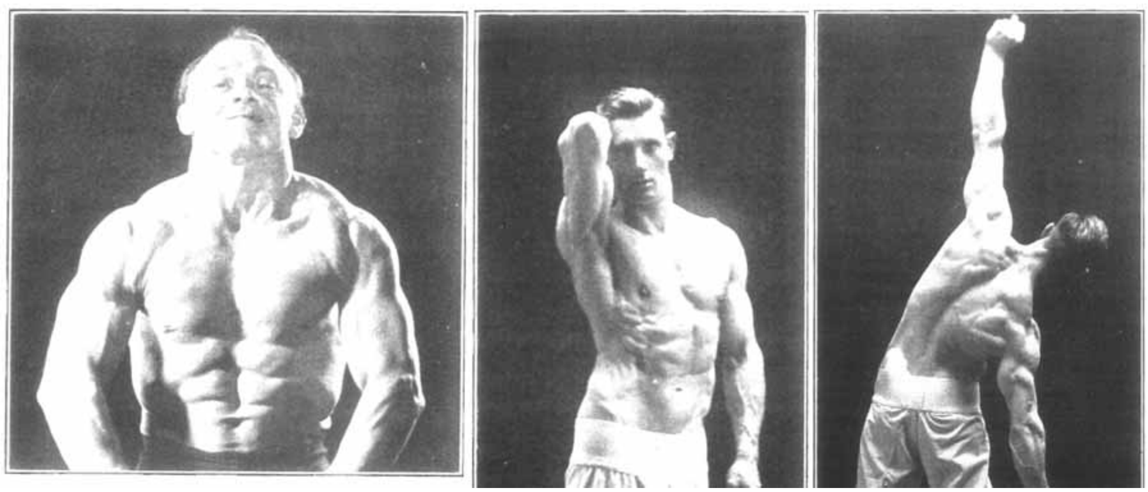
Matching the brevity with intensity factor is a brilliant theory that virtually falls into the face of the many so-called experts' opinions. This theory generally is referred to as the High Intensity approach to skeletal muscular training. Unfortunately, like many true innovations, it mostly has been ignored… or has it? The issue is always the overwhelming pathetic mentality that places provenience over reality; or a statement to the effect that "you are not playing by 'our' rules." Therefore, we are back to the user-friendly addicted approach to exercising 'more,' and it fits the bill for the intellectually deprived.

The exercise field continues to spawn a new generation of irrational thinkers of this ilk. Ethics, logic, and the investigation of pertinent history (in any field) takes a back seat and, therefore, the majority must be right! For it was once said, "to be ignorant of what occurred before you were born is to remain always a child." Someone else said, "The revolutions in the history of science are successful escapes from blind alleys." Fortunately, one can glean bits and pieces of sound logic in exercise science over the last century. However the availability of intelligent investigation in this field is in short supply. Historical exceptions of exercise science thankfully did occur between many of the early commercial exploits.

* This section on the history of HIT written by David Landau, www.RationalExercise.com

Gems from History

Just after the turn of the 20th Century, there were more than a few exercise innovators. Of them, there were Alan Calvert, George Jowett and Earle Liederman, and these men were passionate in the pursuit of the advancement of physical training. Alan Calvert entered the physical culture world just after 1900 and literally broke the "cardinal rule" by exposing strongman fakes and frauds in a book called *The Truth About Weightlifting*. The contentious Calvert manufactured the first celebrated progressive exercise tool, the shot loading globe barbell. This started a very valuable trend in progressive and calculated barbell and dumbbell exercise. To Calvert's credit, soon many followed this grandiose idea. The shipping of crates full of heavy barbells and the like became rather costly, and so small bell training then became popular. The small bells and gadgetry, such as the rusty springs, roller dumb-bells, and rubber bands came along with the flux of the mail order "He Man" courses.



Pictures of bodybuilders' developments from progressive barbell and dumbbell training from Alan Calvert's *Body Molding* magazine, 1925.

The most famous "Course," of course, during that era belonged to the legendary Charles Atlas (born Angelo Sciciliano). Muscles were still of great growing concern to the little gentlemen of America, but there was plenty of money to be made. Atlas, "founder of the fastest health, strength, and physique system known," knew this, but he convinced the vast majority that he had indeed found the "secret."

At about this time, everyone seemed to have his or her secret. The big muscle boys came in the form of Professor Albizu, Siegmund Breitbart, Charles MacMahon, Michael McFadden, Lionel Strongfort, and Professor Titus. Their exploits pleaded for everyone to become "strong." They all claimed that they knew each others' "secrets," asserting to all who would listen, that each one's particular system was by far the greatest.

In spite of all the riffraff, there were a few gems of written information that stood out for those that were serious. The platform therefore was set to deliver what the public wanted, and from that some of the sound few were able to deliver some of their truths. Early on, it was Liederman who warned about the dangers of overtraining, back in the mid-1920s, when he noticed (negative) changes that were undesirable. Gross overtraining led to losses not only in muscular size, but functional ability. But, alas, it was a time when weightlifting caught the fancy of quite a few, and there were muscular gains that had to be seen to be believed.

Alan Calvert started a publication called *Strength* magazine. Originally it was mailed with his barbells, but then became a sought-after muscle man subscription. The small journal showed outstanding examples of what proper and brief strength training could produce. Alan Calvert clearly understood the value of specialized and individualized training. He saw that class drills (aerobics) were a complete waste of time, and the simple personal attention given to a student with progressive dumbell/barbell training from 15 to 30 minutes was far superior. But when some (exercise) seemed to be good, more had to be better… or at least according to the public's perception.

Be that as it may, there was quite a following of the progressive theory of advanced barbell training. One has to understand that this was a time before the use of squat racks and where one had to learn to "rock" the bar onto one's shoulders without the use of spotters. The elements and environment necessitated brevity and infrequency, and recommended/required rest between such bouts of training. If you were training in the middle of the winter in most of the early gyms (dungeons) and did not get out of there in a hurry, unavoidably you could have frozen to death, and so the conditions were something short of desirable. The opposite occurred in the hot summer when air conditioning came from a rust-covered old fan if you were fortunate.

Either by design or requirement, brevity and intensity was evident from early on and it obviously kept many from doing any more than necessary. In an ironic twist of fate, it was a man who made his living from selling early oil burners, Bob Hoffman, who single-handedly kept weightlifting afloat for decades. He put all his resources together and started The York Barbell Company (1932). Being a passionate follower and competitor in the iron game, Bob read all he could get his hands on, including many of Calvert's prior works. Deducing from what he read, Hoffman then set forth to write what was his favorite courses, and they sold for decades. Bob took the national weightlifting team and personally shouldered all of the responsibilities in leading a team that dominated worldwide for decades (before steroids, HGH, insulin loading, and blood doping). He built the largest human performance facility and employed many of the athletes involved. York Barbell became the leader and clearinghouse for training, bodybuilding, and weightlifting through the 1950s. Hoffman was a purist and placed emphasis on basic lifts done intensely every other day and he obviously laid precedence for some rest between bouts of exercise.

In 1962, Bob wrote an article in his magazine *Strength and Health* that would shed a light of reason in a field full of major myths and superstitions. MC–MM, or Muscle Contraction with Measured Movement, was an application of slow/controlled repetitions in which the weight/load was lifted in 10 seconds, lowering 10 seconds, and then with a 10-second rest between the 10-10 reps. This led to his landmark book called *Functional Isometric Contraction*. Bob had a variety of strength training protocols in the book, and all proved to be "High Power." A half-dozen basic exercises were all that were needed. Bob insisted he had, indeed, prescribed slow intense training for 30 years previous, but never in exact written technique. It must be understood clearly that of the "Power" systems Bob started, 10-10-10 really was for perfecting the human muscular form, keeping "father time" from creeping up on his athletes and bodybuilders, in addition to making better athletes.

10-10-10 was used rather successfully with some of the weightlifters. Tommy Kono, a World Champion Olympic Weightlifting legend is quoted as saying that the system was used long before 1962, and it produced rather good results. Weightlifting champion Bill March claimed great results from training with static holds and isometrics at different angles inside of 10-minutes, conceivably ever other day, as he was told by Bob Hoffman. Many lifters did whatever Bob espoused, and when Robert told one what to do, they did it with no questions asked.

Many books appeared soon after as a result of the benefits of this high intensity approach. Too bad, it (isometrics) was becoming perceived more as a fad, rather than a scientific approach to exercise. *How to Exercise Without Moving a Muscle, Power of Isometrics - One Minute a Day, Three Times a Week,* and *Isometrics: The Amazing New 10-Second System for Figure Control, Strength and Health* were books that became the rage in physical culture. Unfortunately at about the same time, a new wave of weightlifters (that went along with the decline of American Weightlifting) appeared on the scene emphasizing drugs and marijuana, without the work ethic and discipline. Bob Hoffman's era of dominance was coming to a near end. As a result this opened the door for a new wave of muscle publications. There were magazines such as *Muscle Training Illustrated, MuscleBuilder Power, Physical Power,* and *Iron Man,* and of them, Joe Weider's *Muscle Builder Power* became the rule of the roost.

Weider's courses and magazines started to dominate the Muscle Wars with his "Super Systems" of training, which touted muscular results per mega, multi-set/rep training. Even though his designer routines became the vogue, there were bright ideas from the real hardcore muscle mags. *Iron Man Magazine's* Bruce Page wrote a few brilliant articles emerging about high intensity training that emphasized a very slow movement in the mid to late 1960s. Mr. Page came up with the brilliant concept of intra-muscular tension. He felt that using a more moderate weight load during exercise and then co-contracting the muscles used, would stimulate far better gains, while keeping one from destroying one's joints. He sensed that even though it was understood that the champions had reached their peak in muscular development, there were better ways to strive for more, and the attitude of pushing harder eventually would lead them to a better physique. Page also realized that counting reps was a waste of time and was part of the limited mentality in bodybuilding dogma. He advocated pushing the muscles to failure, and he noticed the muscles fatigued under no set number.

Bruce Page definitely knew the value of intensity of effort, whilst many were continuing to promote magical and mythical allotted numbers including the famous "8 sets of 8." There seemed to be no end in site, with many training for 20 sets per muscle group, 3 to 4 hours, 6 days a week. It was rumored that west coast bodybuilders were spending 8 hours in the gym daily and that some would come back for their evening "sessions." The multi-muscular/set gurus had their books and courses to follow and with the popularity of the "new" protein formulas, it was a match made to last. Meanwhile, coming straight from the jungles of Africa, a man would deliver the *Bulletins* of high intensity training, that would set the exercise field right on its head.

The King has Arrived

Arthur Jones was a man on a mission. He was a one-hundred percenter, dedicated to every field he ever challenged. Whether it was missions to hell hunting wild crocodiles, live episodes with poisonous rattlesnakes unrehearsed on his TV show *Wild Cargo*, or close encounters with the dangerous rhinos of Nepal – Arthur Jones seemed to live high intensity. Working out since the late 1930s, Jones endured workouts that would have killed the average man. He trained in a variety of ways, but always all-out in his efforts to stimulate maximum muscle size. But Art discovered rather quickly that doing more exercise was not better as he was led to believe.

Not satisfied, he ventured to and trained at the original *Vic Tanny's* in California. He sought answers to his questions at the time, and left in disgust when he found out the so-called experts knew nothing of value. A voracious reader, combined with being a genius, internally he knew that no matter what he did, eventually he would not be denied. His exploits led him eventually to Tulsa, Oklahoma, where Jones started training at the local YMCA and that is where he first attempted building better training equipment. Art was interested solely in his own physical improvement, as he saw flaws in traditional equipment and training. (One has to understand that this was a passionate hobby for a man that was by trade a trapper, zoo owner, inventor, big game hunter, CEO of a bush airline, camera man, and movie/television producer.)

As a result of much involvement in these other fields, he fell in and out of training. But still, when the thought occurred, he excitedly referred to anatomy books and cadavers, from which he graphed and drew up diagrams wherever possible. He became fanatically determined to build the ideal exercise machine. Unsatisfied and being a perfectionist, he trashed hundreds of prototype "flops" throughout the 1950s until the late 1960s. (This aspect continued with Arthur even when Nautilus was at its peak, where in a separate warehouse, there were many discarded imperfect machines that simply did not pass his inspection – tons of them rusting and gathering dust.)

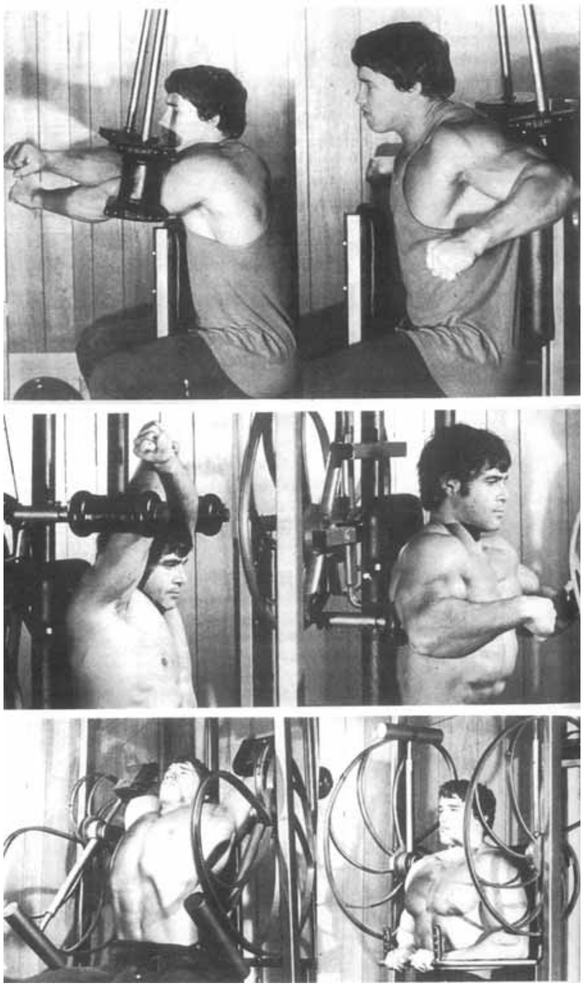
His story has a Horatio Alger twist, when without money and literally broke (borrowing $2500 from a sister) and with an over expired credit card, Jones set sail to the Senior National Weightlifting Championships and the Mister America Contest in 1970 to unveil his first "successful" exercise contraption called the Blue Monster. And the rest is history. The Blue Monster as it was called, was the very first acceptable version of the pullover. Arthur referred to the machine as the upper body squat. Red Lerille, 1960 Mr. America winner, impressed by Arthur's ingenuity, purchased one of the very first commercially offered pullovers from Jones.

Jones spent two weeks at Red's gym instructing clients on a four-station "jungle gym" that he assembled from scratch. This was an early four-station plate loading Nautilus unit. Red said that Jones did an awesome job, revolutionized exercise equipment, and stated emphatically that the Nautilus name stood for quality! Arthur, Red expressed, was atypical, always looking for something different.

Franco Columbu pictured in an early plate-loading pullover machine

Another classic story was Arthur's very first order. There was a phone call from a gentleman by the name of Jack Feather. Feather was notoriously known for developing the Sauna Belt, Mark Eden Bust Developer, Trim Jeans, Astro Jogger, Slim Skins, Vacuum Pants, and the Cambridge Diet. Criminal frauds, as Arthur would put it, but never the less, Feather wanted a run of the new Nautilus Machines. Arthur literally had to retrieve a crumpled piece of paper from his wastebasket that had the "projected" machines that were yet to be prototyped. A cashier’s check immediately arrived and Arthur then built the machines, wherefore Mr. Feather finally had his line.

Finally after so many years of unsuitable attempts to design the ideal muscle machines, he had something of value. Jones worked 18-hour days; he had to since the demand for the miracle barbell was exceeding the supply. Jones solved the problem rather quickly by building warehouses and manufacturing plants that neared the size of general motors. Nautilus had arrived and it began to dominate the exercise world for the next 15 years. He did not stop there, as he proceeded to build the largest human performance laboratory that made anything that was considered second place, look like a shithouse.



Arnold Schwarzenegger and Franco Columbu training at Nautilus Headquarters on the early rowing torso (top), behind neck (middle), and Super Pullover (bottom) units.

Note: Arnold met Joe Cirulli of Gainesville Health & Fitness and told Joe that he (Arnold) had never met Arthur Jones. Pictures have to been taken to indicate otherwise, as Arthur informed the author.

Jones, wrecked physically by his long bouts of weight lifting, learned the hard way through his vast years of experience and observation and as a result, devised the bibles of bodybuilding and exercise. *Nautilus Bulletins I* and *II* were the best-written journals of all time. Arthur stressed muscular physiology and strategized a system of training that had never been seen before or since. His style and approach was inimitable. He knocked down all the walls of the traditional approach, and told everyone to go straight to hell. People, he espoused, were spending way too much time in the gym, hours where only minutes were required. Importantly one must remember that the original Jones axiom was, "if in doubt about proper speed of movement, THEN MOVE SLOWER!"

Some took notice of Arthur's position on muscular exercise and one in particular, was the weightlifting legend Tommy Kono, from the Hoffman stable of years past. Kono tracked down Jones, spent some time with him, and told Jones that he was enlightened by his sound logic and intelligence. Jones loved any audience and would entertain and speak to whoever would listen.

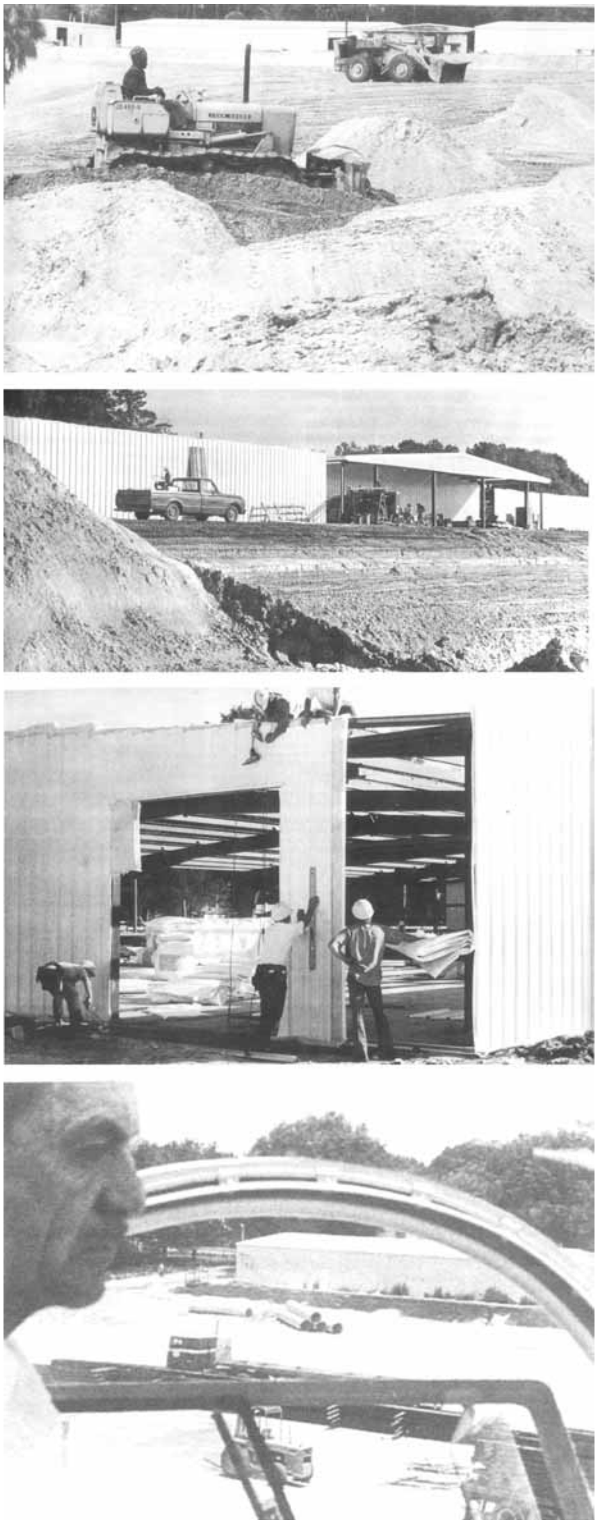
In the meantime, many articles and ads started to appear in the "real" men's bodybuilding magazine, *IronMan*. People read the startling truth, and according to Art many of them agreed with his hard hitting direction. People actually would write the magazine eagerly waiting for not only the articles, but more so for the outrageously elaborate ads that adorned *IronMan*. More letters flooded the offices, from many excited about the immediate progress from training hard on Nautilus equipment. It was thought that *IronMan* had financial interest in the Nautilus Company… that was how great the exposure was.

As a result, bodybuilders soon rushed to the headquarters that were located in the sleepy hollow of Lake Helen, Florida. Those included among the many were Arnold Schwarzenegger, Franco Columbu, Sergio Oliva, Casey Viator and, of course, the Mentzer brothers. Arnold Schwarzenegger stayed for a week and after his first training session he said, *"In the past I have had trouble standing up after training, but this is the first time I've had trouble lying down."* Arnold was completely stunned by his workouts and gained four pounds within one week, increased his arm size, and had nothing but praise for Arthur and his machines. Franco was so sore after his first workout that he had difficulty walking for several days. Columbu, in particular, gained muscle mass quickly, learned much from his visit and stayed a bit longer.

Sergio Oliva became one of the poster children and stayed for a few years. (Later to his regret, he wished he had stayed longer.) Arthur prepared him for the NABBA Mr. Universe Contest in 1971, training Sergio exclusively with high intensity. Ironically, the non-beknownst financier of NABBA was the one and only Jack Feather. Oscar Heidenstam was the known head of NABBA and the Mr. Universe Contest had pitted Frank Zane, Bill Pearl, and Sergio. During the prejudging it was seen by Arthur that the comparisons were not side-by-side. The reason, according to Arthur, is that "Sergio literally dwarfed Pearl," who was eventually judged the "winner."

Feather, who had a home in London where NABBA was hosted and, where Arthur stayed later that night, received a phone call. The phone rang and it was was Oscar Heidenstam. Jack had Jones listen on the other line and Feather said: *"It will never happen again!,"* and promptly hung up the phone. Feather saw where the cards were stacked and immediately withdrew his association with NABBA.

Meanwhile, back at the "ranch," Jones' popularity and notoriety had became worldwide. His training methodology became allied with amateur and professional sports. In order to expose his Nautilus Training Principals, he began writing an onslaught of more articles, attacking every training "theory" that ever existed, including many of the exercise equipment manufacturers. The Universal exercise equipment company made the huge mistake of tangling with Jones. He was immediately accused by them and people of the like of being a member of the Mafia, professional killer, and a heroin smuggler. After writing a classic article/ad in the *Athletic Journal*, November 1974, entitled *Criminal Fraud or Unbelievable Stupidity*, Arthur pretty much summed it up by saying, *"People do not mess with lunatics, that's also true of geniuses. But it's easier to convince people you're a lunatic. The appearance is the same, the effect is the same, they leave you alone."* Arthur did not care, he knew that the exercise field was up to its ears in bullshit and decided through a very long process of trial and error that things must change.



Nautilus Headquarters under construction, with Arthur Jones supervising from a helicopter (bottom)

Change it did, from spectacular results with West Point to indirectly leading a High School Weightlifting team to a reported five state titles with over 202 consecutive wins; the results were not to be denied. The Colorado Experiment was by far the most elaborate study done on one human being (Casey Viator), than any that ever existed in the field of exercise. The results were astounding and word got out. Soon just about every NFL football team, NBA basketball team, and Major League baseball team started using his equipment and with great success. Thousands of Nautilus centers opened along with Jones' staunch principals. Arthur soon became a celebrated speaker and lecturer. Arthur loved delivering his dictums and stories about the many sagas and adventures to uncharted territories in Africa, as well as ongoing research. He appeared on television, hobnobbed with the stars, and still went on African ventures, including flying back 63 baby elephants to his home *Jumbo Lair*. The Nautilus name had become so strong that it was synonymous with Kleenex, Fridgidaire, Coke, and Vaseline.

Then things started to change. Quite possibly from working the incessant 18-hour days, being a one-man show, fighting the media, and his battle with the IRS, his interests waned, as Hoffman's did before him. Arthur was headed for other venues. He planned to dominate the television industry world wide, but with the best-laid plans of mice and men, his interests changed specifically to spinal pathology. MedX became his new brainchild and the rest is history. If one man ever laid the mark on High Intensity training and living, it will be ever Arthur.

The Offspring?

High Intensity training has developed into many modes that have been developed from many systems of exercise in its history. Today we see anything from the sledge hammer style of Ken Leistner[1] or the meticulous – the careful, exacting approach of Ken Hutchins[2]. Nonetheless, there remains a war over what high intensity training is and should be. But high intensity training still refers to the least amount of exercise required to stimulate the muscles' growth structure and the magnitude of the overload involved. That basically has been established for decades. The sword is a matter of choice, as philosophies vary.

None, however, have been able to capture the magic when the lion roared and reigned supreme, as did one Arthur Jones. The legacy has been passed on over the ages. We have seen the torch passed on from Alan Calvert, all the way through Arthur Jones, but no one has really taken over where Jones has left off. High intensity training still remains on the back burners in the exercise industry.

Meanwhile, the fables still continue to rise, and pile like a virtual junk heap, no better than the vagaries of a child. To this day Arthur continues to say, *"the old myths continue, with quite a few new ones."* Regardless, the future may have promise, and as Kim Wood (a man who was a great part of the Nautilus Empire) recently said, *"High intensity will rise again, or will it?"* Since this has been a brief History, it will be up to the reader to ponder.

-End-

[1] Dr. Ken Leistner, who was there in Lake Helen, not long after Arthur arrived in 1970, lived in the "castle" of high intensity. He was involved in the initial outright hard groundwork for the Nautilus company.

[2] Ken Hutchins was involved in various Nautilus projects, although his "claim to fame" involved an osteoporosis project whereby he had subjects move very slowly at a 10/10 cadence, a method that became the backbone of the Super Slow exercise protocol.

Negative Perspectives of High Intensity Training

The concept of HIT derived from the teachings of Arthur Jones, inventor of Nautilus and MedX machines, and which reached its pinnacle during the 1970s. Arthur did not refer to his 'method' of exercise as HIT, but as 'proper exercise.' It was Ellington Darden, a colleague and employee of Arthur's, who created the moniker HIT, based on the notion that Arthur Jones believed that a high 'intensity of effort' was a primary of anaerobic (strength training) exercise.

As Arthur stated, "you can train hard or you can train long, but not both." Certainly this is true since lackluster effort never optimized any person's muscular strength or size, and as one trains harder, less set volume and frequency can be tolerated. Hence, there exists a comparison between 'quality' and 'quantity.' More will be said about 'intensity of effort' in Chapter 2. Jones also believed that the body should be trained as one unit, since it recovers as one unit. The most popular HIT directions tend to be full-body training, although the philosophy does extend to split routines.

Nonetheless, the idea of brief, intense exercise is not new, and not something Arthur invented or discovered. For instance, Eugene Sandow, a person considered to be the first 'modern' bodybuilder, wrote in his book *Strength and How to Obtain It* (1895) that a person's exercise regimen should not take more than 20-30 minutes, and performed only a few times per week. And George Eiferman, a past Mr. America (1948), trained full-body brief sessions, three times per week.

And so how did our perspective on 'proper' exercise change? Prior to the introduction of anabolic steroids (late 1950s in America), people exercised much differently, including bodybuilding and powerlifting enthusiasts. Unfortunately, the combination of superior genetics (of the world champions) and drug use eventually dominated the fitness magazines, and this continues to influence magazines and how the public thinks about exercise to this day, as well as exercise certification institutes. And by blindly following the latest trend or gimmick, regardless of the inconsistencies, contradictions and irrationality that may exist, there remains a challenge to the productivity of brief, intense exercise. This exists for a number of reasons: 1) because high-intensity exercise is 'too simple', and this means less marketing potential to 'dazzle' clients; 2) people have not experienced 'how' this exercise should be applied properly; and 3) often people are unwilling to exercise as hard as is necessary to derive any benefit from a significant reduction in set volume and frequency.

The other issue is political. People embrace different exercise philosophies, for whatever reasons (such as, "if it works for me, it will work for everyone"), and when those philosophies are challenged we become emotional. Simply walk up to anyone in the gym and indicate that what he or she is doing is wrong, and a heated argument will begin. Do the same with a fitness 'authority' and printed and public retorts (often based on ignorance) will ensue. Likely the most stringent and untrue squabbles have arisen against high intensity training as opposed to any other method of exercise, which evolved most heavily from the Joe Weider magazines that promoted a different philosophy of exercise and the use of free weights, and which had to annihilate the much popular and effective Arthur Jones Nautilus machines and his 'brand' of exercise.

Understand that Arthur believed in intense exercise, as did most people who promoted the benefits of strength training and bodybuilding. But Arthur went one step further to suggest that to make exercise as intense as possible, and to challenge the muscles effectively, movement needed to be 'full range,' and that doing so required technological advancement in exercise that exceeded the barbell and dumbbell.

The issue of full range exercise is a complex issue and it means more than simply moving a resistance from a point of stretch to a point of contraction. Rather, it means providing an equal and sufficient amount of resistance throughout a muscle's range of motion in order to develop equally the entire range of motion, and to match the force output/torque generated by the working muscles. These requirements do not exist with free weight exercises, as evidenced in the barbell curl and barbell bench press, and it should be apparent that optimum resistance is found only at the 'sticking point' of those exercises and not equally throughout a full range of motion. Exercise authorities did not care for Arthur's suggestions, perhaps because they never thought of it first, because they believed Arthur was trying to make money from his machines (which took money away from them and the sale of their free weights or other exercise paraphernalia), or it challenged their beliefs and authority in the industry… or a combination thereof; an issue of 'power' and 'money.'

Nonetheless, Arthur concluded that there are nine (and possibly ten) factors required for full range resistance, all of which are accounted for with his Nautilus (and later MedX) machines, and with some other equipment manufacturers, but certainly not with pulley systems or free weights.

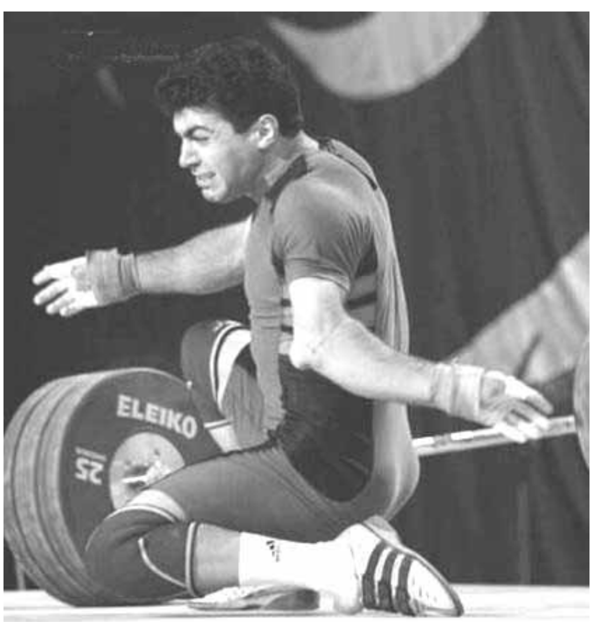
1. Rotational form of resistance, rotating on a common axis with the involved joint of the body.
2. A direct form of resistance that is directly imposed upon the body part being moved by the muscles being worked.
3. An automatically variable form of resistance that varies instantly as movement occurs.
4. Balanced resistance that varies in accordance with the actual requirements of the muscles in different positions.
5. Resistance that is provided in a stretched starting position; which requires a range of movement in the machine that actually exceeds the possible range of movement of the user.
6. Negative work potential.
7. Positive work potential.
8. Pre-stretching, a factor that is required during the last one or two repetitions of a set of high-intensity (of effort) movements, to enhance contraction and work production.
9. Resistance that is provided in the finishing position of a movement, the only position of full muscular contraction.

10. An unrestricted speed of movement *may* be a requirement, on the basis that no one know what the ideal speed of movement should be and, therefore, it should not be restricted, as per isokinetics or hydraulic-type equipment. Certainly explosive and ballistic style of exercise does not provide full range resistance, even if using variable resistance machines, primarily because the measure of momentum reduces significantly the degree of tension experienced by a muscle throughout the exercise's full range. Consequently, movement needs to be "slow enough."

Another consideration for the critical irrationality of high intensity exercise stems from the certification companies. Some people who run these organizations know very little about proper exercise application, although they genuinely may be passionate about fitness. Other authorities are involved in particular philosophies that *must* run counter to high intensity training.

For instance, one 'strength and conditioning' organization was established by Olympic weightlifters, and to this day this group continues to maintain control of the organization and endorse such practices (even among athletes who do not compete in the sport). Olympic weightlifting requires specific technique, plenty of warm-up, and avoids exercise to muscular fatigue in order to maintain proper mechanics. After all, it would be very difficult to 'throw' a weight in a particular manner if mechanics falter due to fatigued and 'rubbery' muscles. The photos below clearly indicate what can happen even when muscles are fresh!

And so, since this group avoids exercise to muscular fatigue, they then discriminate against high intensity exercise, as to suggest that HIT is dangerous (sure… look at the photos below once more of a non-HIT environment) or not very effective so that their explosive, ballistic, and sub-fatigue 'brand' of strength training reigns superior.



HIT vs. HVT

Every existent has but one truth, an identity that cannot be contradicted; and it can be neither ignored by man's conceptual faculty, nor escaped if man is to exist and prosper within reality. Identity is an irreducible primary, an axiomatic concept that is a fundamental of epistemology (the study, nature and acquisition of knowledge) and metaphysics (the study of existence). As a rational animal, man has a unique identity, as does an apple, a tree, celestial bodies, and everything within the universe.

Anaerobic exercise (strength training and bodybuilding) likewise is a specific concept within reality, and it has a specific identity and, therefore, it has an exact meaning or definition. If it did not, the term anaerobic exercise could not be integrated properly with other abstractions or concepts and it could not exist per se. The exorbitant perceptions of what constitutes anaerobic exercise is so varied among the so-called experts that it has become a nebulous approximation to the extent that the average individual is perplexed in securing its proper meaning. Accordingly, anaerobic exercise must be grounded on non-contradictory principles.

Anaerobic exercise typically is characterized as being high in intensity/effort, relative to aerobic or endurance-based exercise, and it is brief in duration, with sets lasting under two minutes tension time. This does not imply that an activity short in duration must utilize the anaerobic system, or that the activity must be intense. Rather, and <u>in terms of strength training and bodybuilding</u>, to derive an optimum benefit, anaerobic exercise *must* be intense. If it is intense, the length of the workout will be brief; and the sets should be brief enough (less than two minutes) to avoid entering the aerobic energy system as to shift the focus from endurance and toward developing greater muscular force and muscle mass. Deviation from this direction challenges the nature of anaerobic exercise such that it no longer exists as it should – with more emphasis placed on endurance than strength or muscle – or the length of the workout becomes such which cannot be tolerated (for very long). Although the approach to strength training can vary in application, such as the number of repetitions, repetition velocity, and time under load, it must do so within limited reason in order to hold true to its identifying methodology for optimum progress. In effect:

> Any amount of exercise strain represents a negative factor, in that, to a degree, any exercise performed at all causes an inroad into the body's recovery ability. Therefore, exercise must be regulated cautiously to the extent that if an inroad into recovery ability is made, then that much of the body's resources must be used to compensate for the exhaustive effects of the exercise, i.e., to overcome the inroad. This leaves that much less of the body's limited reserve of resources for the overcompensation of growth. Accordingly, exercise must be prescribed in an appropriate measure in accordance to each individual's needs, goals, abilities, and limitations for optimum progress.

> In order to increase muscle strength and size, one’s existing anaerobic, functional ability must be challenged, with an increase in weight and/or repetitions/tension time on a continual basis, or an alteration/variation within the program as to cause a “shock” or agitation to the system. Anaerobic stress physiology indicates that this is accomplished best, so long as overtraining is non-existent, by exerting each work set relatively hard, and up to a point of momentary muscular fatigue, regardless of the number of repetitions, e.g., 8 or 12. Effort of a modest degree likely will not challenge current functional ability, and such effort may only maintain current strength levels at best, unless a trainee is relatively new to the exercise experience. Attempting to increase the number of sets to make up for the lack of effort will enhance muscular endurance more than muscular strength and size.
>
> There must be adequate recovery time between exercise sessions to allow replenishment of fuel resources, compensation (tissue remodeling), and eventually overcompensation in the form of new muscle growth or lifting proficiency. Although stress has a localized effect on muscles, stress also has a general effect on the entire body. Consequently, recovery time between sessions for unrelated body parts is just as important as recovery time between sessions for the same body parts. Training again, before the body has had sufficient time both to compensate and overcompensate may hamper progress and result in generalized fatigue (overtraining).

The above may appear quite evident upon review, and it comes from a person (myself) who exercises very intensely most of the time and with low volume; low, at least, *relative to* fitness magazine hyperbole. Regardless, high-volume, orthodoxy collectivists are eager to refute that brief, intense methods of strength training can work, yet this idea contradicts itself when the collectivists indicate that there is more than one valid approach to strength training. Usually "other" ways are accepted, so long as the underlying philosophy of a different way does not contradict or challenge their position to any great extent. Those who promote sub-fatigue, high-volume exercise are adamant in their position since a reduction in quantity and an increase in quality exposes the frailty of the high-volume application, i.e., “why do 'that many sets' when you can get the same results with 'these few sets'”? Moreover, when it is demanded that the volume ‘experts’ in fitness magazines state their theory of exercise, and the relationship of the theory’s underlying principles, there is a dead silence — blank out!

In essence, the two principal genera in strength training can be reduced to:

1) High-intensity Training — HIT; maximum effort on nearly all work sets while very few sets per exercise and/or muscle are incorporated (exactly what "very few" means remains subjective among trainees) on an infrequent basis (ibid.). It is difficult to classify HIT any differently, since the *only* commonality among HIT enthusiasts is the belief that one should exercise very intensely, i.e., as hard as possible.

2) High-volume Training — HVT; moderate effort for the most part, while multiple work sets (3-5 on average) per exercise/per body part/per workout, on a frequency of 1-2 times per week for each exercise and/or muscle. This is reflective of most fitness magazine recommendations, although HVT correctly would refer to "doing more than is appropriate relative to an individual's tolerance to exercise strain, either over the short- or long-term." In other words, the volume is "high" rather than "appropriate" or "ideal").

Unfortunately, these lax abstractions and descriptions further accommodate the more explicit ideologies and perceptions of the fitness industry. For instance, some advocates of intense training avoid direct sets for smaller body parts to justify any crossover effect, e.g., biceps stimulation during lat pulldowns. Others include multiple sets per body part, of different exercises; doing so may or may not be too voluminous, but which volume is relatively diminutive when contrasted to typical high-volume methodologies, e.g., 10+ sets per muscle on a regular basis.

The HVT Weider approach to bodybuilding recommends an ambiguous 3-5 sets of 3-5 exercises per muscle, whereas periodization fluctuates the intensity (weight in this case), volume and frequency from one cycle to another, depending on specific training goals, i.e., strength, power, mass, endurance. (The implementation of varying seasonal training is ludicrous considering that the prescription for power is not much different than it is for strength, yet one must increase strength to increase power.) Although perception of what constitutes purposeful strength training application is a source of chaotic diversity, even among colleagues of similar methodologies, the argumentative and theoretical discrepancy between HIT and HVT remain obvious and most debated.

Unfortunately, both groups are wrong. Some people cannot or are unable to train to muscular fatigue and, as a result, they do require more sets (whatever the measure) to obtain a positive exercise response… or have set variables implemented to increase exercise demands, such as 1¼ reps, negative reps, or descending sets. Some people simply perform too much work, and they believe that any “champion” routine found in a magazine must work or that the program eventually can lead a naive individual to "super-muscle stardom".

The purpose of this section is to address:

1. The physiological effects of both HIT and HVT (high volume* to the extent that there is a clear reflection of fitness magazine methodology, as per the classification above).
2. How HVT proponents perceive HIT, and the myths underlying their beliefs.
3. The basis for which HVT should be considered, and the myths underlying some of those beliefs.

Physiological Effects of HIT and HVT

HIT, i.e., great effort within an anaeorbic environment, has distinct attributes via a cause and effect relationship. Increases in phosphogenic concentration and glycolytic substrates (both energy-yielding components of anaerobic exercise) and increases in anaerobic enzyme activity are most notable. Consequently, there also is a gradual abatement of aerobic-oxidative enzymes with long-term implementation of HIT-style of exercise. Moreover, and primarily because of the longer recovery intervals between workouts than is found with a HVT-style of exercise, HIT has been linked to enhanced immunogenicity. These factors are reflective of the SAID principle, whereby the physiological mechanism maximizes and adapts to a particular stressor for survival, if there is sufficient time in which to do so.

Conversely, exercise that encompasses low to moderate intensity of effort or repetitive bouts of activity on a highly frequent basis (5-6 sessions per week) increases aerobic-oxidative enzymes and mitochondria proliferation to, likewise, adapt to a particular physiological environment — that of endurance.[3] This may not be true of all HVT routines, but the potential for such adaptation increases as the measure of volume and frequency increases while intensity decreases.

Moreover, although HVT exercise approaches do incorporate very intense effort interspersed throughout total workout volume, there is a disproportionate inclusion of lower-intensity, valueless effort. In effect, HVT becomes a psychologically dependent provocation of how much one can endure to prove merit as an "iron warrior," among other psychological strangleholds; hence, there is a focus on total work volume and frequency rather than quality and effort. As a result, there is a proclivity for fast twitch fibers to atrophy because of overuse stimulation.

* The term high volume is a subjective description to indicate that a trainee uses “a lot” of sets and exercises for a “long” time, c.f., championship bodybuilding routines found in fitness magazines. More specifically, as I define it, **high volume** refers to <u>*superfluous* exercise volume (and frequency) relative to that which is necessary to stimulate *maximum* results with the least amount of exercise demands possible</u>. This is relative to whether the goal is growth, strength, or endurance, and based on individual needs, goals, abilities, limitations, and preferences. The total measure of volume and frequency, moreover, must be balanced with intensity of effort, since the harder one exerts in a workout the fewer the sets and the less frequently that a trainee can tolerate them. As can be deduced, high volume is relative to the individual in question, in that it is the individual that governs what is “high volume.” What may be high volume for one trainee may be ideal or insufficient for another. And, as stated above, that measure is further dependent on the quality (effort) and frequency of exercise.

3 Pollock, Michael L., et al. *Muscle*. Rehabilitation of the Spine. Mosby-Year Book, Inc., 1993. p. 264.

Physiologically, exercise that enhances strength and muscle is an unnatural event; it is one that force adaptation to a greater apex of functional capacity and ability for the purposes of survival. When subjected to strain, whether it is exercise, extreme cold, or emotional and psychological anxiety, specific events transpire, as discovered by the father of modern stress research, Hans Selye, including:

1. An enlargement of the adrenal cortex.
2. Atrophy of the thymus, spleen, lymph nodes, and all other lymphatic structures of the body (including a large reduction in eosinophil cells [a type of white blood cell]).
3. Ulcers in the lining of the stomach.[4]

Therefore, although exercise for the biceps may have a localized effect on the myofibrillar architecture within the biceps, there also is a generalized (endocrinological and neurological) effect; performance of 15 sets for the biceps means performance of 15 sets for the body. This empirically is evident the day following a hard leg workout, whereby a trainee feels reluctant to exercise the back, chest, or some other muscle because of an overall feeling of general fatigue.

To compare the cumulative, depleting effect of two approaches, consider the following: 1 set per body part x 7 body parts x 52 occasions per year (i.e., once every 7 days) x 25 years = 9,100 bouts of stress. Conversely, 10 sets per body part x 7 body parts x 73 occasions per year (i.e., once every 5 days) x 25 years = 127,750 bouts of stress. This equals fourteen times the magnitude of strain as that incurred by the sample HIT approach. In all fairness, and if one were to avoid the mathematics above, the difference would not be fourteen times, since the physiological strain of maximum effort HIT work would close the gap. However, there is still a difference in regards to physiological wearing, including immune system problems and osteoarthritis as a trainee grows older. Moreover, there would have to be evidence that the HIT approach could produce a similar response in muscle and strength as the HVT approach to compare the two measures above and to do so objectively.

If, for the sake of argument, the above HIT program produces no better results than a moderate-intensity HVT and more frequent approach, it would appear logical to increase effort and reduce both volume and frequency to some degree in the HVT program. In this respect, exposure of long-term systemic wear-and-tear on the body would be more appropriate by way of a reduction. The goal, then, would be to discover how *hard* one can train, for the most part, and how much volume and frequency *is necessary* in order to achieve an optimal response relative to the intensity level, and in accordance with a person's goals and trainability.

[4] Selye, Hans. *The Stress of Life*. McGraw-Hill. NY: 1978.

It should be evident further how irrational and pointless it is to create categories of HIT and HVT. Both groups follow the same principles of exercise science. Both groups integrate the same concepts within their workout philosophies. It merely is the direction and measure of those concepts and principles that vary, and this is true even within the same faction, whether HIT or HVT. Those within the HIT group argue among themselves in regard to "how much" is ideal or necessary. One such argument came from Mike Mentzer; he believed that one set per muscle is all that is necessary to stimulate growth, whereas other HIT enthusiasts argued this point vehemently.[5] The HVT group tends to argue less among itself, although each sub-group or individual will promote specific methods still, and while following the *same* principles and concepts.

Erroneous Perceptions About HIT

<u>Perception</u>: "It is impossible to knock off the entire motor unit pool of Type 1, Type IIa, and Type IIb fibers from only one set."

Foremost, what is meant by "knock off?" It can be presumed that the term refers to the eventual firing and exhaustion of all motor neurons, thereby all muscle fibers within said muscle group become fatigued. Notwithstanding, it is implausible to "knock off" all motor units (and likewise all fibers) even by means of multiple sets. A person would have to exercise to the point of being unable to contract the muscle. Even then, there would be muscle fibers not exhausted. The remaining fibers simply would be unable to lift the weight of the arm. In any case, not all myofibrils exert to the same magnitude throughout the length of a sarcolemma. Only as a muscle loses its mechanical efficiency — since muscular force deviates from a straight line — whereby it increases its girth at the point of full contraction, will progressively more myofibrils toward the center of a muscle be called upon to work. This is basic biomechanics. As a result, if an exercise does not afford adequate resistive force at a particular juncture, including the point of full contraction, then specific myofibrils will not work at that juncture.

Second, such a degenerative/exhaustive process, if it were possible, painfully would yield total incapacitation of the muscle for several days, accompanied by a reduction in potential functional capacity for several weeks. Overuse atrophy of the fast twitch fibers correspondingly would eventuate, since the endeavor to "knock off" all motor units would demand outrageous volume and intensity of effort.

Consequently, just how many sets, then, are warranted to "knock off" all motor units? And, if "all motor units" was an exaggeration of proposition, how many must be "knocked off" to bring about profits in strength and muscle? HVT proponents have suggested that ten or more sets are the requisite number, as reflected by their training protocols. But how was that conclusion reached, and which is it *exactly*: 10, 11, 15, 18, 20 sets, or more?

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[5] Even the term HIT is inappropriate since "high" intensity could mean any value that is high relative to some other value. Ninety percent of one's full capacity certainly is "higher" than 89%, and 89% is higher than 70%, etc. If part of the philosophy of HIT is to train as hard as possible on all work sets, it should be termed *Maximum Intensity Training*.

To suggest 10, 15 or 20 sets arbitrarily is fatuous, since the performance of more sets than is necessary to achieve an optimum response becomes a superfluous act of masochism, and this would serve only to make greater inroads into recovery ability.

Strength training is the use of progressive resistance methods to increase the ability to exert or resist force; hence, the Overload (progression) Principle. To wit, constantly challenging current strength/force capacity, by either using more weight for the same number of repetitions, or performing more repetitions with the same weight (within reason, and without an attempt to optimize endurance), strength will increase accordingly. For some people, maximizing muscle mass does take more volume than one or two sets, but not much more, as suggested by the magazines, and so long as the effort is high enough. Fundamentally, the focus needs to be on quality effort rather than "how much volume," although volume is important. The idea is to challenge a muscle's capacity, and it is up to each individual to discover how many sets and how much frequency is required, relative to the intensity of effort. The idea is *not* to see how many sets can be performed in a workout.

Perception: "High intensity may be good in theory, but not in practice."

A theory cannot be good and with its practice flawed. If a theory is not true to its corresponding actions, it no longer is (nor was it) a valid theory. The practice of specific, conscionable actions is the result of a theory. Moreover, HIT is not a theory, but a method and philosophy based on principles of exercise theory, viz., intensity, volume, frequency, load, and specificity.

Perception: "High intensity proponents are dogmatic."

Dogma, as Ayn Rand stated, refers to *"a set of beliefs accepted on faith; that is, without rational justification or against rational evidence. A dogma is a matter of blind faith."*[6] If actions do not follow an established theory, they are left to pursue 'gut hunches', 'blind faith', and 'subjectiveness.' Hence, the actions become random and arbitrary. Both HVT and HIT follow the same principles of exercise science. Both groups, by and large, are just as dogmatic as the other since it is the measure of those principles over which people argue; yet it is the measure of those principles that *each individual* must come to discover for him or herself.

Perception: "Considering the warm-up sets that HIT trainees implement before their work sets, it really is the same thing as HVT; they still are performing 2-3, or more, sets per exercise."

There is nothing written in stone that HIT exercise cannot implement warm-up sets to facilitate a more efficient workout. In fact, in order to use a progressively heavier weight safely, to reflect the Progression/Overload Principle, often it is necessary to increase body core temperature and psychological preparedness prior to the work set(s). However, a warm-up that progresses beyond the requisite amount necessary generates additional

[6] Playboy interview. March 1964. p. 39.

strain and fatigue, and this can diminish total muscle force output. Hence — and this is the most crucial distinction between HIT and HVT — as with the workout, the warm-up must be kept to the minimum that is essential, and this will make the least amount of inroads into function so that the greatest effect can be achieved with the work sets.

For instance, if 100 pounds for 10 repetitions is used for a work set (and continued to the point of momentary muscular fatigue, or close to it), an ideal warm-up could consist of: 50 pounds x 3 repetitions, followed by 75 pounds x 1-2 repetitions, followed by the work set. Of course, the amount of warm-up depends on many factors, but this "minimal" warm-up does exemplify a point, which is: The purpose of the initial two sets is to prepare both mind and body for intense work; yet, those sets neither fatigue nor challenge functional capacity, but serve to enhance it. As can be deduced, and if we consider the extremely low effort one would expend on the initial two sets, those sets cannot be labeled 'work sets', nor do they contribute, to any consequential degree, to the total volume à la HVT.

Many HVT enthusiasts perform at least 2-3 preparatory sets on every exercise, and some HVT enthusiasts "pyramid" the weight up then down for up to 10 sets per exercise. This is pointless and an overkill in many respects. Usually exercise methodology is based on social beliefs, such as the power and effect of "numbers", and certain numbers repeat even in exercise, such as 1, 3, 5, and 10 (a 'nice' round number), or combinations thereof, e.g., 6 (<u>3</u> x 2). It is no surprise, then, that many people perform three sets of most exercises, and often three exercises per muscles and usually 8 to <u>10</u> repetitions per set.

For those concerned about the risk of injury that might follow a brief warm-up, bear in mind that when slow, continuous, non-bouncing movement is implemented — as typically suggested by HIT practice — risk of injury remains relatively non-existent. Injury occurs when forces exceed the integrity of soft tissues, or from the inability for the tissues to remodel because of overuse, viz., too much volume and frequency and not enough recovery. Both factors can arise even under exorbitant warm-up conditions, and this can arise under explosive, bouncing, plyometric *and* HVT practices, regardless of the number of warm-up sets.

A well-known periodization proponent advocates an extravagant warm-up prescription of 5 sets of an exercise, using the same weight, for the same number of repetitions (e.g., 5 sets x 5 repetitions x 300-pounds), and working to muscular fatigue only on the fifth set. He believes that one must 'own' the weight before subsequent workout increases are made — thus the need for replication. First, if the trainee were to complete the requisite number of repetitions with a given weight in the initial work set, would he then, at that time, not "own" it? If not, who does? Was the completion of that initial set a hallucination in the mind of the trainee... a fictitious occurrence?

Second, the degree of energy squandered on the initial 4 sets of 5 reps renders the athlete incapable of using a possibly greater weight than that used eventually on the fifth and final set. Perhaps he could have used 320 pounds for 5 repetitions if he only had performed a minimal (of what is necessary) warm-up, rather than repeating a task that was already within his capacity. Analogously, one does not observe sprinters running the 100-meter dash 4 times with slightly less than maximum effort. This would tax physical ability to run an optimal race later. Rather, sprinters jog lightly on a spot, and walk about to increase blood circulation, and then perform mild stretching for the ankles and knees. They may run the 100 meters 1-2 times at a *modest* pace to prepare mentally and physically better, but at all times the preparatory effort remains essential, yet minimal.

Perception: "Compare the number of champions using high-volume to that of high-intensity. Obviously high-volume is more productive."

Champion bodybuilders and strength athletes are the elite within the population; outliers with respect to physical potential for building strength and muscle mass; and on the far end of a bell curve distribution. Moreover, these individuals often utilize nightmarish quantities of drugs. They represent an infinitesimal segment of the population, and they are not a representation of the average resistance trainee. Hence, such a statement commits the Fallacy of Hasty Generalization, since this bases the presumption on instances that do not constitute a fair sample. It also commits the Fallacy of False Cause, since champion athletes are the result of their genetics and drugs, not of their workout practices. They most likely would have succeeded despite the method of exercise. Similarly, 80% of low back pain sufferers convalesce regardless of the intervention, or lack thereof, and this indicates that traditional chiropractic and physiotherapy modalities are not very effective or necessary.

Many strength coaches who follow periodization and HVT methods boast of their clienteles' progress; that they train NFL, NHL and NBA athletes with great success; that they are top coaches or trainers to the champions. Again, star athletes are not representational of the typical, and little consideration is given to the coach who teaches the sport skills; the latter may have been the reason for the athletes' success. Nor have I known any 'average' trainee who has made optimal progress on a HVT or a periodization approach as advocated by fitness magazines, with the exception of neophytes who suffer from under-use atrophy, and who often progress on nearly *any* program despite the program's inefficacy.

An objective indication of what exercise methods work would require a copious, random sample of experienced resistance trainees. They need to be experienced since nearly all beginners initially make progress on any program. Then one would need to measure their progress over a year span using a reliable body composition analysis system to determine ratio differences of lean and fat body tissue.

Accurate strength increase measurements also would be useful, but testing must be conducted on specialized equipment to account for impact forces, stored energy torque, gravity, exact positioning, and internal muscular friction, such as the equipment offered through MedX (www.MedXonline.com). Of course, even individual genetic factors would have to be accounted for, and this is impossible relative to today's technology and knowledge.

Perception: "Although some champions have used HIT, many have returned to a HVT approach."

Justification as to why a trainee might return to a different and possibly less effective method of exercise is complex and various. Some champions have done so as a result of peer pressure, philosophically suggesting tribalism and not individualism (since most of their peers are doing 'something else'). They commit a breach of integrity, in that they know what is right then they proceed through rationalization; they defy the truth that a different approach might be more effective and logical. (This is not to say that it is.)

Other champions can see a more easily traveled road through mindless, low- to moderate-intensity exercise and increased anabolic steroid use. Conversely, HIT irrefutably is hard work, and it requires the utmost concentration, determination and motivation for optimum success. Notwithstanding, HIT application can be tolerated by nearly anyone — including the elderly — who has clear, objective goals and determination, and such training is not reserved for a special 'breed' of individual. However, not everyone has the mental fortitude to sustain such rigors continuously.

Another explanation for shifting from a HIT to a HVT approach may be downright ignorance in comprehending the vital connotations in regulating intensity, volume and frequency. Years ago, upon obtaining Mike Mentzer's *Heavy Duty Arms* course, I integrated enthusiastically the suggestions within my routine, and I performed one set of rest-pause curls for biceps, together with a pre-exhaust set for triceps, once weekly. In consideration of my previous exercise practices of at least 10 sets for each muscle, such training truly was low volume. During this time I concentrated extra hard on the effort and quality of movement. After four workouts, I increased my upper arm size by a half-inch. Upon witnessing the expedient results, I thought that doubling the volume and frequency would be better. The conclusion was flagrant overtraining, overuse atrophy, and a loss of my gain. I concluded thusly that Mike Mentzer's methods did not work, whereto I reinstated a HVT approach with less intensity of effort in a quest for progress that did not happen nearly as quickly. Rather than having realized that as I became larger and stronger that I would require more recovery time (as I was warned), I substituted this advice with the current-day orthodoxy: "be persistent and you will triumph" and the infamous "more is better."

Sometimes more is better, and sometimes less is better, whether in regard to volume, frequency, or intensity of effort. But it is illogical to uphold a philosophy that is based on a particular direction in measurement rather than the discovery of what the ideal measurement may be at any time in one's exercise career.

Perception: "HVT is hard on the joints and tendons."

It may be presumed that such a notion stems from the nomenclature HEAVY Duty, as coined by Mike Mentzer, in the belief that the weight (force) must be 'Heavy.' This is not so. Or perhaps there is confusion over the term 'intensity,' since in HIT it means effort, whereas in HVT it means 'weight.' Therefore, those into HVT think that high-intensity exercise refers to high loads.

Of course, as with any weight training method, progressively heavier weights routinely are used with HIT; but HIT typically incorporates moderate-force activity, associated with a resistance that can be handled for 40-120 seconds tension time[7], while moving under muscular control. Some methods, such as rest-pause (3-4 mini-sets of 1-3 reps, with 10-15 seconds rest between attempts) will necessitate heavier weights, but this method should not be employed nor is it recommended on a continual basis.

What is "hard" on the joints and tendons are impact forces and excessively frequent exercise. In the first instance, muscular control eliminates dangerous impact forces; jerking, bouncing, and throwing. In the second instance, too frequent exercise will not allow for adequate tendon remodeling. Tissues proceed through a period of transient weakness as they adapt to exercise, and the tissues' mechanical strength diminishes at some point when remodeling. This situation is reflective of both muscle and tendon, although it is slower for tendons because of a poorer blood supply. Hence, a sequence follows of degradation → compensation, → overcompensation. If there is inadequate time for necessary adaptive responses, these changes cannot transpire, regardless of the exercise protocol — high- or low-volume... high- or low-intensity.

Another long-term effect from too much exercise is osteoarthritis, and this is evident with people who train too much, too often, and with poor technique. In effect, the goal should be to perform only enough exercise with sufficient intensity of effort to achieve one's goals, regardless of the philosophy or methodology in place.

Perception: "HIT has some value, but it is short lived."

If a particular method of strength training has value, why would it be short lived, or why would it cease to be of value? A value is that which one acts to gain and/or to keep. As Ayn Rand stated, "*Value presupposes a standard, a purpose and the necessity of action in the face of an alternative. Where there are no alternatives, no values are possible.*"[8] If "high-intensity" has value, it must possess such in the face of an alternative that does not have that particular value; the only diametrical alternative is "low-intensity". Since the value of high-intensity effort is to invoke optimum strength development and muscle growth, low-intensity would be the opposite, viz., a high rate of muscular endurance.

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[7] Arthur Jones, the father of "brief, intense exercise" recommended a weight that would allow at least 8 repetitions, and preferably 10-12 repetitions, but not more than 20 repetitions.

[8] Rand, Ayn. *For the New Intellectual*. Random House. NY: 1961. pb 121.

The reasons for something to be short-lived are numerous, including over adaptation to the stimulus and that the demands of exercise are too low or too high (the measure of any of the principles is not sound and relative to the trainee at any particular time). These factors also are possible with any program, including those with a focus toward higher volume and moderate intensity. It is not the intensity of effort that necessarily is at fault, but a combination of the factors that constitute the program as a whole.

Perception: "The only reason HIT initially works is the result of previous overtraining conditions supervened by additional rest time and briefer training sessions."

If volume and frequency reduction resulted in strength and muscle mass increases (the desired commodities), what purpose lies with a subsequent volume and frequency increase? Why would one leave an effective program for another program that would cause overtraining? Why fix what is not broken? Obviously, altering training demands allows for either repose (fewer demands) or to challenge the body better (greater demands). Consequently, doing too much volume necessitates lower volume, and doing a very low amount of volume, relative to an individual's upper tolerance level, necessitates a higher volume... some of the time. An ideal direction is to cycle exercise demands, and the above suggestion can be turned around and applied to a HVT approach. In effect, "the only reason a HVT approach works is that the previous reduction in exercise demands lasted too long or was too severe.

The body is constantly in flux, and what may be too much at one point may be too little at another point, and vice versa.

Perception: "I've tried HIT, but it didn't work for me."

The reasons behind this claim are numerous, but they can be limited to four main causes. First, most HVT trainees perform exercise with reckless biomechanics, and this includes bouncing and explosive movement. If this were not so, it would be impossible to perform the volume these individuals enthusiastically incorporate, of at least 10 sets per muscle and upward of 20-25 sets as evidenced with many magazine-based routines. Such shoddy technique is evident if one were to view the various bodybuilding videos available on the market, or if one were to visit nearly any gym.

To illustrate, I trained a woman whom, at the time, performed 3-5 exercises for 3 sets each per muscle. She trained each muscle once every 5 days. I drafted an initial routine that consisted of 1-2 sets per muscle, with a frequency of once weekly for each. Three weeks into the program, she felt discouraged because of non-existent strength and muscle gains. Upon observing her form, it became apparent that her muscles were not being stimulated sufficiently, through controlled tension relative to the volume and frequency; she jerked the weights about ferociously at times. After a reduction in velocity, and demonstrating various isolation techniques, she literally felt debilitated within a few sets, much to her stupefaction and delectation. Thereafter, she produced the best gains of her exercise career in a matter of two months. Since there is a distinction between quality and quantity, the two could not coexist — just as Capitalism and Communism or logic and mysticism cannot coexist.

Second, HIT training requires high motivation to sustain the rigors, and this is why it is all right to reduce intensity of effort and to increase volume now and again. It is not an easy approach to exercise, nor can everyone cope with the assiduous and requisite psychological and physical challenges. If a trainee is not 'there' at all times, optimal progress cannot be anticipated or achieved. However, such is required when exercise is reduced to as few sets as advocated by HIT proponents. HITers believe that the goal is to challenge the muscles as hard as possible; the goal is not to discover one's stamina. To maximize strength and muscle *is* hard work, and hard work must be conducted in a brief period, whatever the measure happens to be.

Third, trainees who are new to very intense exercise, who have trained with a high-volume and moderate-intensity beforehand, oftentimes are overtrained or they are not attuned mentally for HIT application. In the former instance, being in an overtrained state requires rest, not continued exercise of a more intense nature, even with a reduction in set volume. A drastic reduction in volume and frequency will not prove advantageous always. Once in an overtrained predicament, a total layoff is the only logical recourse, to help return the body to a non-exhaustive and responsive state. Unless this condition is absolute, no method of strength training can be productive, and this includes HIT. In the latter instance, being able to generate maximum effort in a set, both mentally and physically takes time, and a set reduction that is too extreme may not prove advantageous either. Only as intensity increases should volume and/or frequency decrease, to better balance the fundamentals.

Lastly, and most importantly, people who try a new method, such as HIT, try a single program *of a certain measure*, based on a particular philosophy or direction. The measure of intensity relative to the volume, frequency and every other aspect may not have been ideal for that individual. If it were, progress would be optimal, regardless of the "philosophy" or direction of the program.

Perception: "HIT is dangerous."

Some authorities contend that training to muscular fatigue is dangerous, as to suggest that the tissues become so weak that injury is more prevalent while lifting a given weight. However, the opposite is true, and the further one progresses into a set, the safer the work becomes. Conversely, it is the first repetition that is the most dangerous.

To explain, what you feel during lifting is not your actual output (e.g., 50 pounds of force), but a percentage of your output at any particular moment. For instance, if you can curl 100 pounds once, then 60 pounds will feel relatively easy on the first repetition, but progressively harder from one repetition to the next… until the end of the set. And once you reach that final repetition, the 60 pounds would feel as hard as the 100 pounds since you then would need 100% of your momentary effort to move it.

Risk of injury has nothing to do with how hard something feels or how exhausted a muscle is but, rather, the forces involved in exercise. Suppose your connective tissues (and more particularly were the tendon meets the muscle… the most vulnerable area) can withstand 100 units of force, but would tear if it worked against 105 units. The tendon's ability to withstand 100 units will not change throughout a set, whether it is the first or last repetition of a set.

However, muscles are different, in that they may be able to exert 120 units of force, but in doing so would injure the tendon. But with each repetition in a set, muscular force (ability) diminishes. Therefore, if you perform 10 repetitions in which the muscles exert no more than 90 units of force, the muscles eventually exhaust to the point whereby 90 units is their maximum and the tendons never need to experience forces they cannot tolerate.

Conversely, it is at the beginning of a set when muscle strength is greatest, and when it is more common or possible to exert a great amount of force quickly. At the end of a set, on the final repetition, the muscles are too weak to move quickly and can only move slowly against a load, thereby keeping overall forces to a manageable level. In effect, it is when a weight is lifted quickly (explosively) or bouncing/ballistic action that must be eliminated. Therefore, so long as you only produce enough force to move a moderately heavy weight slowly and under control, the forces will never be so great as to cause injury; the forces are never much more than the weight itself.

This is not to say that injury cannot occur under 'to-fatigue' conditions. However, it only is when a person trains to fatigue and loses form (at least excessively) that any risk of injury occurs. However, this is an issue of improper mechanics (which could result from lack of mental focus) and generating unnatural torque on the tissues that poses a problem. And this condition can occur with sub-fatigue exercise practices as well.

Why HVT?

Premise: "It is necessary to work muscles from multiple angles in order to stimulate development and strength throughout the entire strength curve."

Implementing a variety of exercises certainly helps in many regards, and this includes injury prevention. Working the same paths in the same manner can result in overuse injuries and neuromuscular imbalances. In regards to hypertrophy, muscles contract progressively from points of origin to insertion. You cannot, for instance, develop the outer pectorals from the inner pectorals, nor the lower biceps from the upper biceps. However, exercise change, to include sufficient variety in both selection and program strategy helps to keep muscles from adapting to the stimuli. Moreover, this direction is not the sole domain of HVT. Those who follow HIT are free to cycle exercises, variables, etc., within their style of training.

In regard to the acquisition of optimum strength, throughout a full ROM, a viable solution would be to incorporate variable resistance machines.[9] These machines render fairly consistent effort throughout the entire range of movement, and this makes work more demanding as full contraction eventuates, muscular efficiency decreases, and as progressively more myofibrils participate.

However, even variable resistance is not the most crucial factor to acquiring strength — it merely makes the application of exercise more productive per unit of time. Rather, the crucial factor is the effort generated. The deadlift, squat, chin-up and bar dip remain some of the most exhaustive and productive exercises, yet each only tax the strength curve of the various muscles through a portion of their ROMs. The inclusion of additional exercises to work the stretch, midrange and contraction points of a muscle's range of motion is a viable solution, but it must be done cautiously since the more exercises performed in a workout, the greater the likelihood of an overtrained state.

It is true that being strong in the squat does not make one correspondingly strong in the leg press or lunge, since neuromuscular adaptation among exercises differ. However, there are dozens of movements for each body part, and this brings up the following questions: Which exercises should be included? How many exercises should be included? How often should exercises change or vary?

[9] It has been argued that conventional exercises tax only one-third of the strength curve because they do not load a muscle at every point of a ROM adequately. Therefore, greater variety is necessary with free weight and conventional training methods than if one were to use variable-resistance exercise equipment.

As an aside, many HVT authorities clearly understand that being strong in one movement does not make a trainee correspondingly strong in another, i.e., “include a variety of exercises to affect the strength curves at all angles.” Yet some of them cannot grasp this connection within sport specific biomechanics, such as throwing a ball, a football tackle, or rowing a boat, viz., sport specific skills must be practiced to demonstrate strength within the sport properly and optimally. Resistance training merely serves to increase strength generally, thereby force output is enhanced in sport activities. Nevertheless, many coaches are inclined to prescribe power cleans, jump plyometrics, and snatches supposedly to increase an athlete’s overall ‘explosiveness.’ If this method worked, world-class Olympic lifters would, likewise, be world class rowers, football players, hockey players, etc.

Premise: “You require variety in your program, and this means altering training specifics (i.e., strength, power, mass, endurance) and velocity (i.e., slow, moderate, fast/explosive). This can be accomplished only through periodization methods.”

Since the objective of most athletes who follow periodization strength training methods is to increase demands to increase function constantly, viz., the Progression/Overload Principle, the inclusion of specific training methods to enhance *strength* at one point, *power* at another point, etc., is groundless. For example, Strength is *the force generated by a muscle or muscle group*. Power is equal to force x distance ÷ time. Although strength can exist without demonstrating power (i.e., isometrics), power cannot exist without strength being demonstrated. Likewise, speed of muscular contraction is dependent on force (and the skills involved to demonstrate the power of a particular action), since greater force means faster movement.

A person can become stronger without becoming larger, but when a person increases lean mass, the greater cross-sectional area will result in greater force production.[10] Consequently, to include a "mass" phase, whereas strength and power remain in their separate and distinct phases, is irrational; and to include a hypertrophy phase whereby a trainee might not want to become heavier in body weight is irrational. The problem is, few periodization models to which we are accustomed disregard the different phases of physiological goals to be achieved, and they do not address unique requirements of different athletes or trainees in that regard.

[10] There are rare instances whereby a muscle becomes so large that it loses its mechanical efficiency and it will be no stronger, but this is highly unlikely without the combination of anabolic steroids and very good genetics.

Premise: "HVT methods, like periodization implement active rest, and this allows for continued exposure to strain while the trainee recovers. This is known as 'loading' and 'unloading'; the alteration of light and heavy weights from one workout to the next. The result is no loss of neurological conditioning and a constant stimulus for regular progress."

This is where confusion lies, in the premise that lighter weights (even if carried to the point of muscular fatigue) is "low-intensity", as opposed to the "high-intensity", heavier weights. Regardless of semantics, effort is effort, and 'A is A'. Exercise in any capacity, whether light or heavy loads are implemented, physically results in localized and generalized strain on the body. To adapt and grow stronger, the body must follow a sequence of steps: energy replenishment → compensation → overcompensation. If the first and second steps are intervened, through continuous assaults of localized stain, even of varying weights, the general affect on the entire system negates the possibility of overcompensation (as least at optimum levels), and this will hinder progress. The result is an inability to improve, or possible overtraining. "Active rest" is an oxymoron. Recovery and activity cannot coexist, since each has a particular identity and they subsist as separate entities.

Neurological conditioning is not lost over the course of weeks, let alone months. This particularly is true of anaerobic capacity, and it has a much longer deconditioning and detraining period than aerobic capacity. Such is evident with HIT trainees who perform specific exercise movements only every 2-3 weeks, yet they continue to become stronger (more proficient at specific exercises). Moreover, it is not uncommon for a trainee to exclude an exercise for several months, only to resume where he or she left off. The skills of the squat, for example, are not lost from a brief period of neglect, e.g., while leg presses are performed, and such simple tasks cannot be analogous to the technical discipline and cultivation of neurosurgery, for example.

Exercise movements are natural movements in consonance with man's biomechanical tendencies, neither of which demand years of exercise experience to acquire, nor days to relinquish neurological adaptation. A world-class Olympic lifter once stated that after 15 years of training he was not content with his lifting technique. What a discouraging predicament, as this suggests that he must suffer from a physiological condition that precludes him from throwing a barbell overhead – not exactly brain surgery!

There certainly is a time and place for lower effort work. It is not to allow for rest, but to decrease the demands so as not to overreach one's abilities too often for too long. Activity of a lesser demand helps to maintain muscular condition and strength, and to reduce muscle soreness from less frequent and intense exercise, but to imply that it is necessary for "rest" is erroneous.

Premise: "Because of years of conditioning, advanced trainees can and need to perform more sets than beginners."

This is both true and false, and it depends on the context of the statement. Beginner trainees are characterized as having disuse atrophy of the fast-twitch fibers, from lack of previous intense neuromuscular stimulation. Therefore, beginners are more apt to flourish under conditions of higher volume, at least initially and eventually until they adapt to anaerobic conditions and learn to train hard. In effect, before the onslaught of strength training, most individuals possess greater endurance characteristics, as suggested by the SAID Principle and as reflected through their previous standard of low-intensity activity.

Confusion then arises when function fails to improve or regresses. Trainees often are unable to conceptualize why their programs are no longer effective since, up to that point, they produced results. Then they believe that more exercise must be the solution. As a result, trainees often convince themselves to walk further off the beaten path of a rational strength program toward the "more is better" idiom.

Stress physiology adamantly states that as an organism (trainee) becomes larger and stronger, the demands of stress — not its duration — also must increase, and this will alter homeostasis and adaptation, i.e., greater strength and muscle mass. Antithetically, recovery ability remains only modestly enhanced, since it is dependent on the reactionary time constraints of endocrine and soft-tissue remodeling limitations. There is improvement, but it does not balance with strength and muscular progress. Analogously, consuming more protein or vitamins than the body can assimilate and utilize is not beneficial, and this can result in auxiliary systemic strain. Unlike values, ethics and money, the idiom "more is better" cannot be practiced within the discipline of exercise.

On that note, it is true that in order for an advanced trainee to increase function and muscle mass, at least to a noticeable and immediate extent, the demands of exercise must increase sufficiently. This includes intensity of effort, volume, frequency and the use of set variables (as well as a change in the strategy implemented). Obviously if a trainee already is exercising to muscular fatigue, the remaining factors must increase. Regardless of what increases, the problem is that most trainees will implement a program of "more," but they often do not reduce the demands before they enter an overtrained state from doing "more"; to know when to implement "less." In this context, the philosophy of periodization or cycling of demands is vital for long-term success. However, the nature and philosophy of periodization, as it stands in Western countries (strength, power, mass, and endurance phases), is illogical and the recommended training volume and frequency superfluous.

Chapter 2

Fundamentals of High Intensity Training

Overview

In a nutshell, high-intensity refers to exercise that is very intense, i.e., movement that continues to muscular fatigue (or close to it). This does not mean using a maximum weight, since training in that fashion increases the rate of injury and is not as productive for both strength and muscular development. Rather, for growth production, all one needs to do is to produce a momentary muscular contraction, which can be achieved by first reducing momentary ability, i.e., performing that last, seemingly impossible repetition at the end of a set.

Why should a person train to muscular fatigue (at least some of the time)? As per the “All or None Principle,” in that muscle fibers contract completely or not at all, a similar concept exists in exercise application. In order to ‘overload’ a muscle, one must push that muscle beyond normal limits – over and above what it is used to – by means of a sufficient weight and intensity of effort. By exerting a maximum effort in exercise (by the end of the set and final repetition), the maximum number of fibers capable of being utilized during the performance of a set will have been recruited, fatigued and, therefore, overloaded. This is important to realize since sub-fatigue effort will result in less than maximum fiber recruitment, and less than optimum results since the muscles were not pushed to an appropriate ‘intensity threshold’ to stimulate gains.

Consequently, the goal is to recruit the greatest number of fibers and then allow for recovery… to get the job done quickly and to eliminate any unnecessary or superfluous work/sets. One need only compare the stimulus trigger of one set to muscular fatigue (and 100% effort) to 10 sets sub-fatigue (e.g., 75% effort). Repeating the same degree of effort in multiple sets of an exercise does little more than to re-work the same muscle fibers, which digs deeper into recovery resources before any positive change could take place, and if change is possible under such modest circumstances. Hence, no number of easy sets can replace a few very hard sets.

In this regard, exercise needs to be viewed in a similar light to medicine, in that there needs to be a dose-response relationship. With exercise there needs to be a maximum dose of intensity and overload to stimulate a most favorable response, but there needs to be recovery between doses of ‘exercise medicine’ to allow for change to occur. This is necessary since exercise merely stimulates change, whereas rest allows for change. And so, exerting one’s self maximally (with a necessary number of sets) serves to stimulate muscular growth above current levels while disturbing recovery ability as little as possible, i.e., the need for hard, brief, and infrequent exercise.

Being able to train to the limit is easier said than done since it is very uncomfortable, albeit very productive. Most people do not train this hard or cannot train this hard, and some concessions may need to be put in place, such as increasing volume or frequency slightly, or including some sub-fatigue workout sessions to reduce the mental strain of such exercise. This aspect will be discussed later.

Now, it should be obvious that in order to produce a change, such as more strength or muscle, a person needs to train hard; few people would argue with that aspect since no one developed large, strong muscles by lounging on the beach. The primary argument comes from those who do not believe in training so hard that muscular fatigue is reached. Why? Primarily, if a person believes in exercising 4-6 days a week and for multiple sets per muscle (and often upward of 10+ sets per muscle overall), it is IMPOSSIBLE to train with a high degree of effort; there has to be some reservation in energy. If a trainee did not hold back, it would not be long for a person to overtrain and become so fatigued generally/systemically that any motivation or available energy would be of little worth.

Consequently, it becomes an issue of doing too much volume and frequency and not too much intensity of effort. And, in fact, a review of some of the basic principles of exercise will disclose that high-intensity methodology is nothing more than a ‘measure’ of the same aspects that govern any person’s exercise program, and that such methodology is nothing more than an efficient and effective way for any person to exercise if an increase in strength and muscle are the primary objectives.

Basic Principles of Exercise

Regardless of the *application*, of how a person chooses to exercise, we all must follow the *same principles*. In other words, whether exercising for twenty sets or one set, or whether exercising with weights, machines, or endurance training on a bicycle, an individual:

- Exerts effort (intensity)
- Performs a certain amount of activity (volume)
- Does so on a schedule (frequency)
- Must progress in order to improve (overload/progression), and
- Adapts specifically, relative to the nature or type of exercise program.

In effect, these general principles constitute basic exercise theory, whereas how we apply these principles and their *measurement* determines the ‘method’ or style of exercise.

Intensity of effort is the backbone in all this, since it affects how much we progress and how much (volume and frequency) we can tolerate. The ability to *progress* in function, or to *limit the loss* of function as we age is dependent on certain factors. The first factor is how much weight or resistance a person uses. For example, if a person successfully uses more resistance than last workout in a particular exercise, then he or she will increase function because the heavier weight acted as a stimulus and challenge for the body to increase function. The extra weight and challenge tells the body "you better get stronger, in order to prepare yourself for similar future assaults." At the very least, the heavier weight will challenge ability enough to maintain a certain level of function. As one rule of exercise states, either "use it or lose it." If the weight stays the same or reduces, there likely will be enough of a challenge to maintain or limit the amount of functional loss. Therefore, exercise is not always about improving, but keeping what you currently have or slowing down the loss of what you have built up. But regardless of the goal, there still must be sufficient effort in order to use a sufficient resistance.

Consequently, how much we progress, maintain or limit any physical loss is also based on how hard we exercise (intensity), and this affects how much activity we do in a workout (volume), and how often we repeat the activity (frequency). The harder we exercise, the less we can do in a workout and the less often we could or should exercise. Conversely, the more we do in a workout, the easier we must make exercise and the less frequently we should do it. Similarly, the more frequent we exercise, the less we could or should do in a workout and the easier the exercise should be. An obvious pattern should be noticed, in that there must be a balance among these three factors.

These three factors (intensity, volume, and frequency) have a bearing on how much weight should be used in a workout. For example, if a person exercises very hard then heavier weight can be used than if a person does not try very hard. If a person decides to exercise for a long period or quite frequently, then he or she cannot use as much weight. This last aspect is true because all the fatigue that results from exercising too often would not allow a person to exercise with heavy weights, and the use of heavy weights would not allow such lifting to occur very often; at least not for long before a person feels lethargic and overtrained.

Sometimes very frequent exercise is a good thing, depending on the goals of the individual. Obviously someone who is interested in muscular endurance would exercise more frequently and for longer periods than someone who is interested in maximizing the development of muscle mass and strength. In this regard here is another rule: "you can exercise hard or you can exercise long, but you can't do both." Don't confuse this with an exhausting activity such as marathon running, which may be fatiguing and may be demanding, but it is not "intense." On the other hand, a 100-yard sprint is so intense that it can only last for a very brief time. Therefore, there is a difference between the concepts of "demanding" and "intense." Both the long distance run and the 100-meter sprint are demanding in their own ways, relative to the time in which it takes to complete each task and the energy utilized by each task within those time frames. However, in order to make a long distance run last for several miles, the intensity of effort cannot be high.

Next, proper exercise prescription dictates that the demands need to be specific to the individual and the goals and needs of the individual, e.g., if a person wants to have very good muscular endurance, he or she should train differently than a person who wants to maximize muscular mass or strength. In effect, to "adapt" in a specific way requires the exercise method to be "specific" so that a person can adapt, or improve particular abilities accordingly. A sprinter would not train with long distance running techniques, and a volleyball player should not practice baseball. Therefore, if a person wants to optimize muscular strength and size, the environment must be anaerobically intense, done infrequently, and for short workouts – the opposite of endurance-based exercise.

Next, it only makes sense that exercise should be done in the least possible (or necessary) amount to produce an optimum response. Think of it this way: In order to make the <u>same</u> amount of progress or results, would you rather do 30 minutes of exercise or 60 minutes of exercise? Any rational person would choose 30 minutes, unless exercise is more of a psychological addiction and there is a preference to exercise more than is necessary. Moreover, we have to consider the quality of exercise and how hard a person exercises. If a person does not like to exercise very hard, that person will need "more" exercise to produce good benefits, but it is a fact that the results will not be as good as compared to a workout that involves a higher level of intensity of effort, relative to and no matter the activity.

So far, all this should make sense. An individual needs to lift a certain amount of weight so that the muscles can resist against *something*. An individual puts forth a certain amount of effort and that effort is relative to how heavy the weight is, how much activity is performed in a workout and how frequently the person exercises. The method/structure or nature of the exercise program should reflect the goals of an individual and what is to be achieved, so that he or she makes progress relative to those goals (if the goal is to optimize physical change, then a program of intense effort and appropriate kcal intake is vital). And, it is only rational that the least amount of exercise be performed in order to achieve the desired results, and that any more exercise than is necessary is pointless.

This last factor is important since exercise theory recognizes that any amount of exercise strain represents a *negative* factor to the body and mind, in that, to a degree, any exercise performed at all causes an *inroad* (a reduction in function) into the body's recovery ability. In other words, the more you do, beyond a certain limit, the harder it is to recover from exercise and the less progress you will make overall. Consequently, exercise demands must be regulated properly to ensure the greatest benefit at the lowest cost – the cost is "effort and strain" on the body and mind, and the benefit is a strong, healthy body.

Since each bout of exercise affects our energy resources, some of the body's remaining resources must be used to replenish and compensate for the fatigue cased by exercise. Unfortunately, like anything else, we only have so much recovery ability, and doing too much too often can make us weak and ill, the opposite effect of what exercise is supposed to do. Consequently, we have our next rule: "that which can make us strong can make us weak." Most important, since individuals vary in their capacities to tolerate exercise, i.e., some people have better tolerance whereas some have less. Therefore, what may be ideal for one individual may be *inadequate* or *excessive* for someone else.

Obviously there must remain a balance among the exercise principles' measurements. Sometimes this means that if one thing increases (intensity of effort) the other things (volume and frequency) may need to decrease. Sometimes if only one element increases – e.g., exercise volume, whereas the measurement of all principles were *ideal* before – the strain of exercise can become so high that a person may require several weeks or a few months layoff from exercise to feel energetic again.

Nonetheless, sometimes it is good to increase exercise to higher levels in order to "surprise" the body and to make the body want to become even stronger and better conditioned. In a sense, this could be called "forced conditioning" since one would be forcing a higher state of physical function; a state that the body would not have achieved under one's usual exercise conditions. Olympic athletes do this all the time: they start off slowly and do a little exercise, then they pick things up and exercise a bit harder, then just before the Olympic games they pull out all the stops and train harder than ever before. However, they only train super-hard for a brief period, in order to maximize the body's response to be in the best shape and condition ever. If they trained like that all the time, they quickly would overtrain and lose function. This is vital to remember, since it is very beneficial and productive to increase exercise demands for select muscles or the body as a whole, but it must be done sporadically.

I don't want the idea of how to balance the principles seem too complicated, but consider the following and why things may need to be adjusted or not adjusted. Suppose a person is following an exercise program that is well within his limits and the program is appropriate. If he were to put forth a bit more effort or add another set of exercise then this would not, necessarily, cause him to overtrain since every person has a "range" in which exercise can be tolerated. It's like having a range or tolerance to heat: one temperature feels good, whereas a higher or lower temperature may not be as comfortable or "ideal" for our bodies, but the temperature differences can be tolerated. If you have exercised in the past, you may have noticed this: you either can do a bit more or a bit less than usual, now and again, without any negative consequences.

But suppose that, at this moment, an individual's program is ideal, and any more exercise *would eventually* cause him to overtrain and feel lethargic because of too much exercise. I say "eventually" because an increase in exercise demands is not necessarily a bad thing if the increase lasts for a short period, whether for a few workouts or a few weeks. But, if this person were to maintain such an exercise program for too long, then he would overtrain. This is what happens to a lot of people: they follow a routine from a fitness magazine, and everything is fine at first. They make some progress and then *eventually* they hit a stalemate and no longer make progress. And, eventually, they begin to lose strength, and look and feel worse. These are telltale signs that an overtrained state has begun, and if they don't reduce the exercise demands then things will only get worse until they have to stop exercise altogether for several weeks or months while they recover from the strain of doing too much exercise for too long.

For these reasons, high-intensity exercise is the easiest to track and regulate. First, if intensity of effort is as high as possible, i.e., a person continues exercise until reaching muscular fatigue (or close to it), then you always are aware of the measure of that variable (or a good approximation). Next, if the program were to consist of minimum values for volume and frequency (e.g., 2 sets for large muscles, 1 set for small muscles and performed a few times per week) because of the high rate of intensity, then it would be easy to determine the effects of increasing or decreasing volume or frequency slightly for any particular muscle or the body as a whole. Compare this to many of the bodybuilding programs in the muscle magazines, whereby a person would perform at least 8-10 sets per muscle and exercise 4-6 times per week. What if 5 sets were too much for a select muscle; how would you know and how would you discover it? A reduction to 9, 8, or 7 sets certainly would not help, and many people would erroneously conclude that if 10 sets were not effective then why not try 11, 12 or more! High-intensity training works because it is simple, easy to determine the effectiveness and future directions, and focuses on quality rather than quantity.

General Exercise Rules

1. **Use it or lose it.** Lack of activity makes muscles and our immune system weak.

2. **You can exercise hard, or you can exercise long, but not both.** Sprinters cannot sprint for several miles. Similarly, if the goal is to increase strength and muscle tissue it is wrong to believe "more exercise is better." In this instance exercise should be hard and brief, whereas muscular endurance would require less intense and longer workouts.

3. **That which can make you strong can make you weak.** We should do just enough exercise to provide a benefit relative to our needs, goals, and tolerances. Doing too much, especially if we exercise hard, can do more harm than good.

Stress Physiology and the General Adaptation Syndrome (GAS)

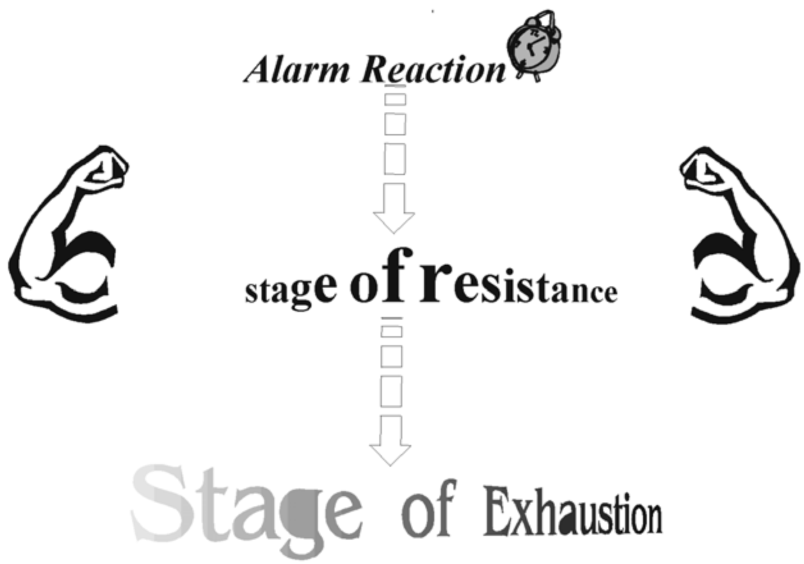
Exercise is an unnatural event, resulting in microscopic tissue damage and metabolic inroading to the endocrine, lymphatic, skeletal, and neuromuscular systems. The body does not aspire to become larger and stronger. It would prefer to abide within its current homeostasis or as close to that level of conditioning as possible. This is why it is vital to implement an exercise program of extreme effort, to stimulate a higher level of adaptation, but to do so briefly to limit inroads into recovery ability, and to do so infrequently to allow for positive changes to occur.

The strain of exercise brings about a disarrayment of homeostasis known as **heterostasis** or a constant state of change, a predicament that is ensued by further adaptation for survival from the stressor of progressively more demanding exercise. Hence, homeostasis achieves a *new* level of normalcy. And because exercise is a form of stress, any measure is a negative factor to a biological entity’s existence.

Biologic stress is the nonspecific response of the body to any demand, a fact first realized by the father of stress research, Dr. Hans Selye. He noticed that regardless of the stressor – so long as it was adequate to alter the current physiological equilibrium, and the amount is typically minimal – whether physical work, extreme cold, intense mental concentration or worrying, the outcome was always specific. He discovered that stress causes:

1. An enlargement of the adrenal cortex.
2. Atrophy of the thymus, spleen, lymph nodes, and all other lymphatic structures of the body – including a large reduction in eosinophil cells (a type of white blood cell). These factors contribute to a weakened immune system, making the trainee susceptible to infections, colds, flues, etc.
3. Ulcers in the lining of the stomach.

These responses occur in every instance (although to varying degrees depending on the extent of the strain encountered). He then noticed that the reaction to stress followed a particular pattern of three stages, which he termed the **General Adaptation Syndrome** (GAS)[73].



Below are examples of stressors and what happens during the final two stages of GAS:

Stress Factor	**Adaptation (*Over Compensation*)**	**Depletion (*Decompensation*)**
Sun	Sun Tan	Sun burn
School	Acquire knowledge	Mental exhaustion
Cold	Shiver	Hypothermia
Heat	Sweat	Dehydration
Friction	Callous	Blister
Exercise	Muscle & strength increase	Muscle & strength decrease

[73] Information in this section adapted from Selye, Hans M.D. *The Stress of Life*. New York: McGraw Hill, 1978.

Relating GAS to Exercise

There both exists a general adaptation syndrome, one that affects the body as a whole, and a **Local Adaptation Syndrome** (LAS). The following example clarifies these two processes and shows how one relates/merges into the other.

Local Adaptation Syndrome

Alarm Reaction: The alarm reaction commences when a trainee warms the muscles, or ignoring a warm-up, commences with the first lift of a set for 10 repetitions, for example. The muscles, at this point, have been given a warning, or a signal that a stressor is being imposed.

Stage of Resistance: As the set continues, further into intensity and toward muscular failure, muscles attempt to resist fatigue, and the stress stimulus, by involving an increasingly greater number of muscle fibers. There is less slow twitch involvement and progressively greater fast twitch recruitment, together with a greater utilization of ATP for energy.

Stage of Exhaustion: By the final and tenth repetition, upon reaching muscular failure, the muscles no longer generate sufficient force to move the weight. Maximum positive inroads using a particular weight have taken place and the muscles feel exhausted.

General Adaptation Syndrome

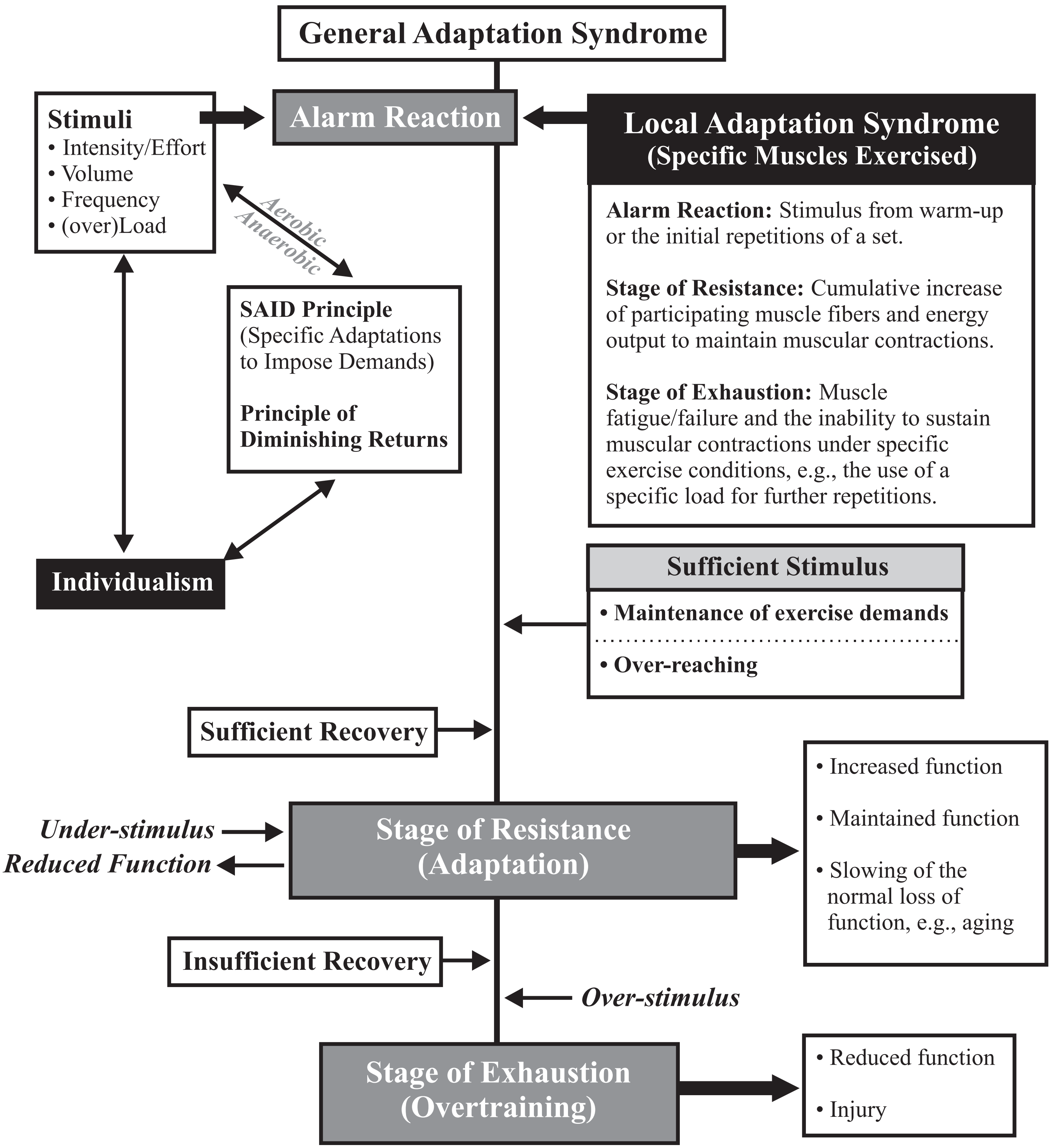
Alarm Reaction: Having reached muscular failure, or some other fatiguing stimuli, the localized stress signals the body to release cortisol, to combat the inflammation in the muscles that resulted from the activity.

Stage of Resistance: Following a period of depletion (immediately after a workout) there begins restitution (equalization or compensation), followed by overcompensation (full recovery with an increase in function). The time interval between consecutive training sessions must be sufficient so that all negative effects of the preceding workout (fatigue, inflammation and soreness) pass, yet the positive fitness gains continue to accrue.

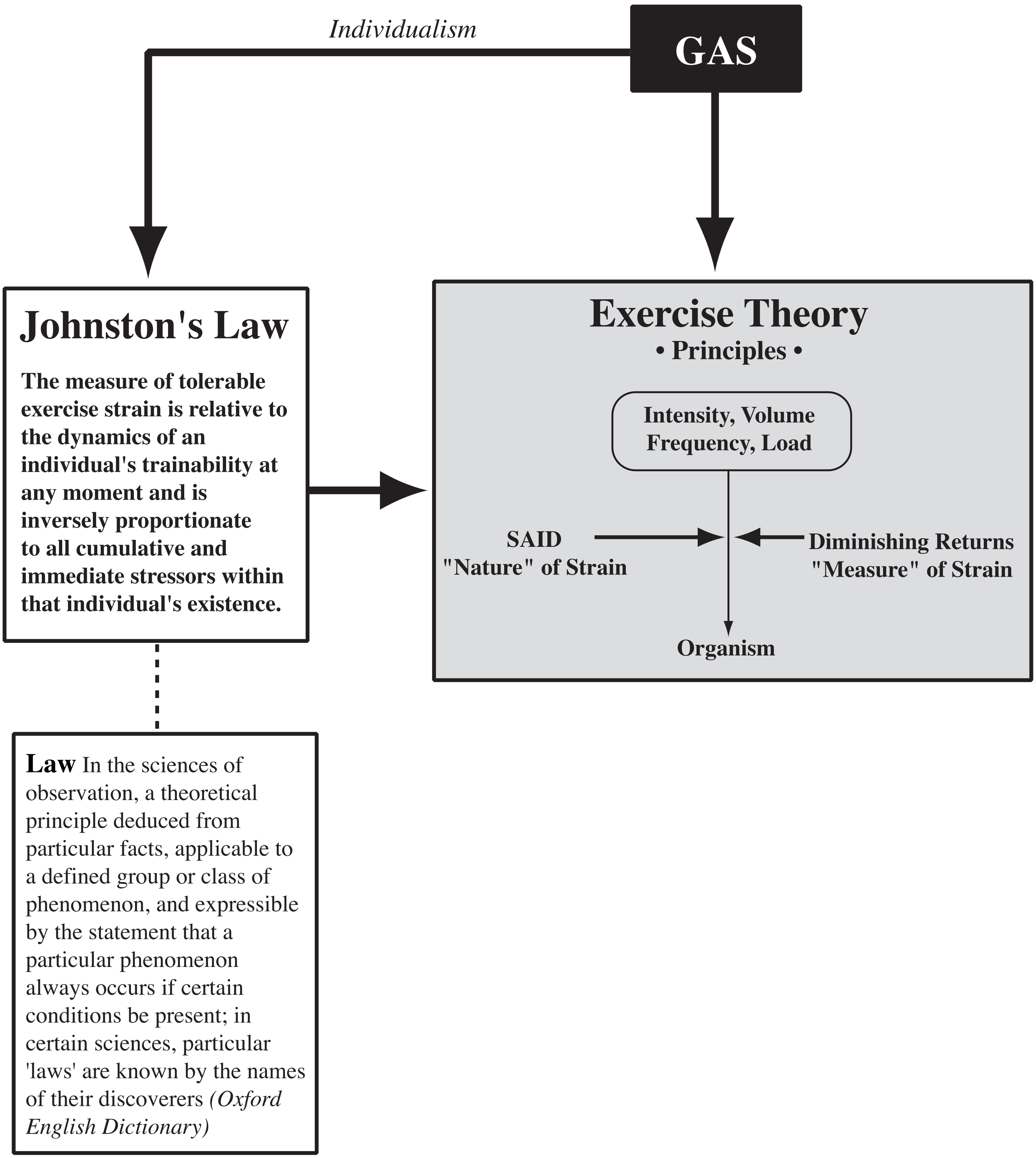
Most important, the individual cannot begin overcompensating if he or she has not at least compensated. This process cannot be hastened without drug intervention. Overcompensation occurs only after certain functions return to normal after the aggitation of exercise, including heart rate, metabolism, and energy replenishment. Further, overcompensation occurs only if the stressor was sufficient to cause a disarrayment of homeostasis, such as using heavier weights, increasing set tension time, implementing unusual training tactics, etc. There has to be reason for the body to increase in function. A stressor of lesser magnitude – one the body can tolerate easily – results in compensation at best, or a return to what was.

Stage of Exhaustion: Barring psychological and genetic limitations, if physiological function fails to improve for several exercise sessions (if improvement is still possible genetically and attempted), or even regresses, it may be an indication that the individual is overtraining or exceeding tolerance and recovery ability, not allowing for compensation, let alone overcompensation. The best and recommended recourse is a layoff from any stressful activity, including exercise, until the trainee experiences a feeling of wellbeing with continually increasing function and motivation. Simply reducing volume, frequency, or intensity may not be sufficient, since there would remain an imposition of stress.

Exercise Science
(A Branch of Stress Physiology)



The chain of events from the *Stage of Resistance* to the *Stage of Exhaustion* is applicable in the context of a single muscle or the body as a whole


GAS
Individualism
Johnston's Law
The measure of tolerable exercise strain is relative to the dynamics of an individual's trainability at any moment and is inversely proportionate to all cumulative and immediate stressors within that individual's existence.
Exercise Theory
• Principles •
Intensity, Volume
Frequency, Load
SAID
"Nature" of Strain
Diminishing Returns
"Measure" of Strain
Organism
Law In the sciences of observation, a theoretical principle deduced from particular facts, applicable to a defined group or class of phenomenon, and expressible by the statement that a particular phenomenon always occurs if certain conditions be present; in certain sciences, particular 'laws' are known by the names of their discoverers (Oxford English Dictionary)

Hormonal Secretions

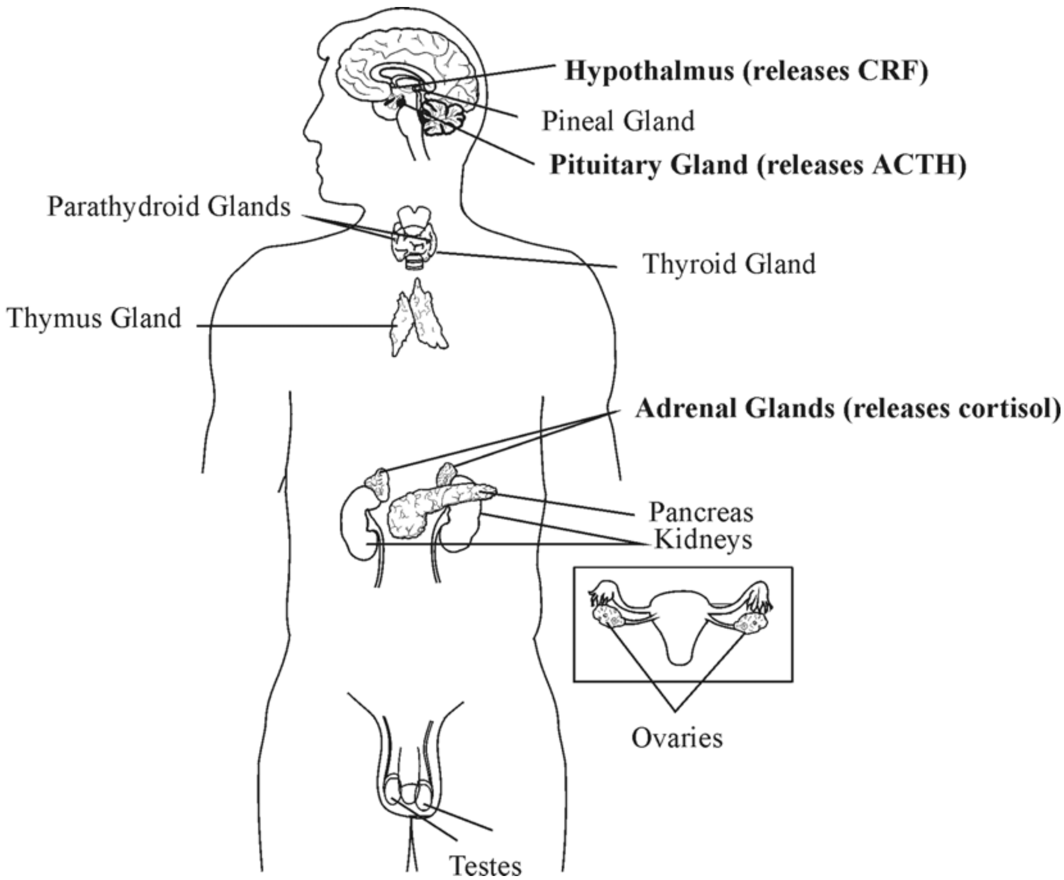
Exercise induces a localized strain within a muscle group and causes general stress throughout the body. This process begins with the hypothalamus signaling the pituitary – by way of a corticotrophin releasing factor (CRF) – to release adrenocorticotropic hormone (ACTH). ACTH travels through the blood till it reaches the adrenal gland, which elicits a cortisol release from its cortex in response to the ACTH (see diagram on next page).

Cortisol is an anti-inflammatory hormone, whose characteristics include catabolism (the destructive phase of metabolism). Not only does cortisol catabolize the inflammation caused by exercise, but also the surrounding muscle tissue. The amount of cortisol released is respondent to both the intensity of the stressor *and* its extent or volume. In other words, the more sets performed – including warm-ups – and the more frequent the exercise, the more cortisol released by the adrenals.

As stated, stress has a general effect on the body, which responds as a whole – whether exercising calves, biceps, or chest. For this reason it is not apropos to train too frequently or on too many consecutive days (unless intensity is rather low) that disrupts the body's ability to recovery from previous exercise sessions. Although beginner trainees often can cope with training consecutive days, due to modest exercise demands and being far from their genetic potentials, the opposite is true for intermediate and advanced trainees. After several months or years of exercise, accumulation of strength and muscle size requires much greater demands to stimulate growth, and it places a greater burden on recovery ability.

Because our bodies have a finite reserve of recovery resources from which to draw, it is necessary to perform the least exercise to produce optimum progress. Each bit of exercise, over and above the minimum necessary, deprives the body of additional recovery resources, and this promotes overtraining.

The Endocrine System and the Hormones Released During General Stress in Response to Inflammation



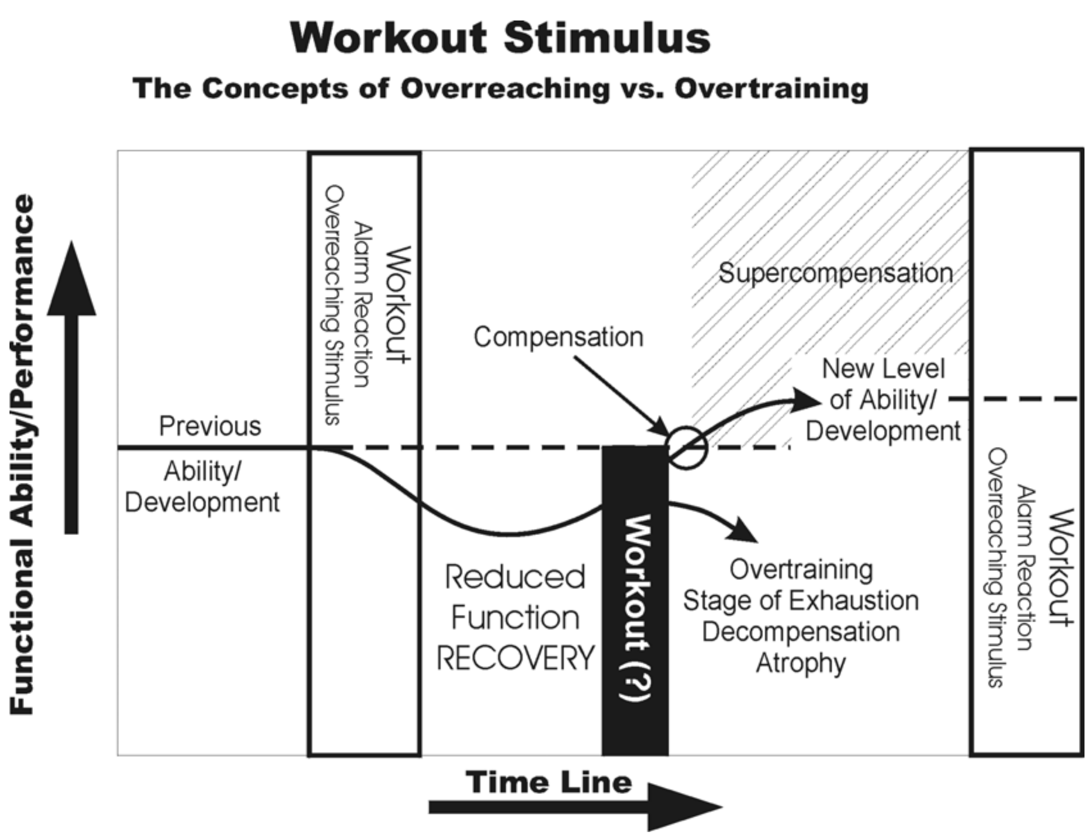
As Dr. Selye stated:

> *Many people believe that, after they have exposed themselves to very stressful activities, a rest can restore them to where they were before. This is false. Experiments on animals have clearly shown that each exposure leaves an indelible scar, in that it uses up reserves of adaptability which cannot be replaced. It is true that immediately after some harassing experience, rest can restore us almost to the original level of fitness by eliminating acute fatigue. But the emphasis is on the word almost. Since we constantly go through periods of stress and rest during life, even a minute deficit of adaptation energy every day adds up – it adds up to what we call aging.* (Selye, Hans, 429).

Consequently, greater function and muscle mass should not be confused with full restoration and beyond. These factors are mere adaptive responses that do not reflect physiological long-term health. Imagine the level of strain incurred by his body each time a trainee reaches a new goal, even if adding but a single repetition to a personal best. If he has been performing three sets per body part, once every 10 days, the amount of stress definitely accumulates over a lifetime. However, if he increases demands to 10 sets each muscle group, once every 5 days, the amount of stress over a lifetime is staggering.

Arthur Jones stated, "*It is only rational to use that which exists in limited supply as economically as possible.*"[74] Because our bodies can supply only so much energy, and with a limited recovery ability, it should be logical that exercise, especially anaerobic exercise, be as brief as possible so as not to cause a state of overtraining.

The objective, then, is to over-reach one's ability to increase function (super-compensation), by training more intensely, using more weight, or increasing set demands (e.g., forced repetitions), but without overtraining. A sub-objective is to complete such workouts as often as is required to both maintain and improve upon a higher level of function that was achieved previously.



[74] Jones, Arthur. *Nautilus Bulletin #2*. Chapter 21: The Recovery Factor. 1971. (Note: The source of this exact quote cannot be found, although recorded at the time of reading it. The statement from Nautilus Bulletin #2 relays the same concept, but in more words).

On the following page are the relationships of some basic principles of exercise science, and how they need to be balanced or considered in order to accommodate stress physiology fundamentals. Thereafter a special look into the concept of *intensity of effort* is discussed.

Exercise Stress Guidelines

1. The more intense the exercise, the briefer the workout must be. In order for exercise quality and effort to be high enough to stimulate gains, the volume must be sufficiently low or, at least, appropriate. The goal is to discover the lowest set volume that will produce the greatest response relative to the level of intensity.
2. Enough recovery time must elapse before the same body part is exercised again. Muscle growth and strength improvements occur during recovery, not activity. If a body part is still sore or tight from a previous workout:
   - Skip a session completely, until the *next* scheduled session for *that* body part;
   - Delay the session and all training for 1-2 days (or until the soreness and stiffness subsides) for a specific body part; or
   - Exercise sub-fatigue to *maintain* with light loads and some “pumping.”
3. If possible, allow 1-5 days rest between workouts, regardless of the muscle being exercised. Whether it is the legs, back, or arms being exercised, any muscle in particular being strained affects the body’s reserve of adaptive and recuperative energy in general.

RELATIONSHIP OF INTENSITY OF EFFORT

Volume	Frequency	Progression/Overload	Specificity
Number of sets (more intensity = less sets per workout)	*Rate of occurrence* (more intensity = less frequency, unless volume diminishes to sustain frequency)	*Increase in weight or TUT* (more intensity = greater chance of using heavier weights or exceeding previous TUT*)	*Strength, muscle mass, endurance* (more intensity = greater ability to achieve goals up to a point)

RELATIONSHIP OF VOLUME

Intensity	Frequency	Progression/Overload	Specificity
Mental and physical effort (greater volume = less intensity unless frequency reduces to allow for additional recovery time)	*Rate of occurrence* (greater volume = less frequency unless intensity reduces to allow for adequate recovery)	*Increase in weight or TUT* (greater volume = less chance of using heavier weights or exceeding TUT because of greater inroading <u>unless</u> overloading in volume is the directive)	*Strength, muscle mass, endurance* (greater volume = less ability to achieve goal of added strength and muscle mass [and even endurance] beyond a certain limit)

RELATIONSHIP OF FREQUENCY

Intensity	Volume	Progression/Overload	Specificity
Mental and physical effort (greater frequency = less intensity unless volume reduces to allow for adequate recovery)	*Number of sets* (greater frequency = less volume, unless intensity reduces to allow for adequate recovery)	*Increase in weight or TUT* (greater frequency = less chance of using heavier weights or exceeding TUT unless volume reduces to allow for adequate recovery)	*Strength, muscle mass, endurance* (greater frequency = less ability to achieve goals beyond a certain point)

RELATIONSHIP OF PROGRESSION/OVERLOAD

Intensity	Volume	Frequency	Specificity
Mental and physical effort (greater overload = dependence on sufficient intensity in order to overload)	*Number of sets* (greater overload = less sets per workout to limit negative effects of excessive inroading)	*Rate of occurrence* (greater overload = limited frequency to overcompensate, unless volume diminishes to sustain frequency)	*Strength, muscle mass, endurance* (greater overload = greater ability to achieve goals up to a point)

RELATIONSHIP OF SAID (SPECIFIC ADAPTATION TO IMPOSED DEMANDS)

Intensity	Volume	Frequency	Progression/Overload
Mental and physical effort (low to moderate intensity for endurance; higher intensity for strength and muscle mass)	*Number of sets* (higher volume for greater endurance; lower volume for greater size and strength, but relative to intensity of effort and individual tolerance)	*Rate of occurrence* (greater frequency for greater endurance; less frequency to tolerate heavier, more intense exercise)	*Increase in weight or TUT* (overload can increase strength, muscle mass, or endurance, which measure is relative to intensity, volume, and frequency)

* **Time Under Tension (TUT)** refers to the measure of minutes and seconds of a set, regardless of the number of repetitions performed during that time, *minus* any resting that may take place between repetitions, such as locking out the joints in a squat or bench press. **Time Under Load (TUL)** refers to the measure of time *including* any brief rests that may occur between repetitions.

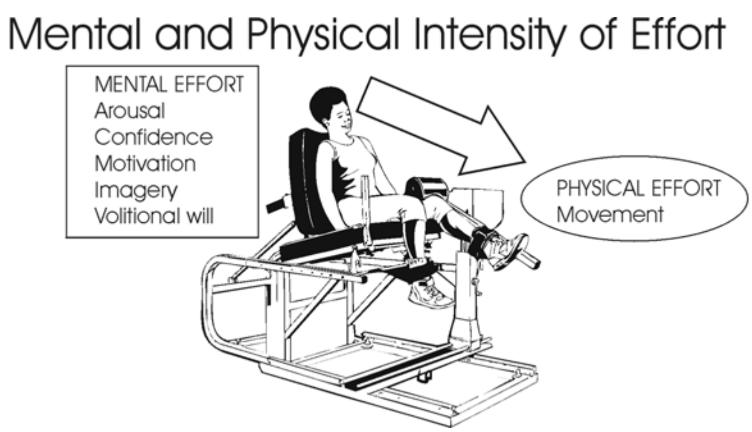
Principle of Intensity

Intensity is the possible percentage of momentary muscular and volitional effort exerted. This means that at any one moment when exercising, you produce or exert a certain amount (percentage) of effort that is possible (or required) to complete a task. Consider lifting a 10-pound weight, whereas 50 pounds could be lifted. In this instance, the amount of effort exerted might be 20% of one's maximum strength ability, whereas 100% effort is required to lift the much heavier 50 pounds.

There are two key elements in this definition: *muscular* and *volitional*. This is important to realize, since there is no mind-body dichotomy in exercise: the mind and muscles work as a unit. Skeletal muscles are voluntary, and this means they must be told to work – they cannot lift a weight without a person's mental consent.

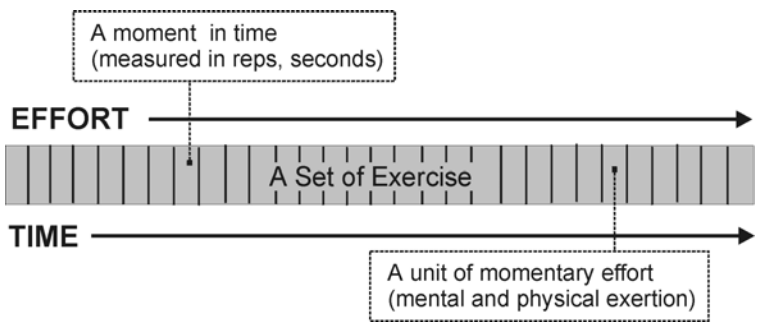
In regard to how much effort is being produced at any given moment, it is impossible to say what the measure is, such as "46% effort at *this* point." But it can be concluded that if a person were to exert maximum mental and physical effort (by the final repetition of a set or if attempting a maximum lift), then intensity of effort would be 100% – whereas complete rest, such as sleeping, would be 0% effort. Not many people exercise to 100% effort. Most people think that once the muscle begins to hurt and when exercise becomes uncomfortable that they are pushing themselves to the limits, but that rarely is the case. Training to muscular fatigue, to 100% effort, occurs when a weight will no longer move after a final repetition, regardless of one's best attempt, and this is a primary premise of high-intensity exercise.

There are a few exceptions when a person should not train to fatigue, because of safety. For example, pushing the deadlift or squat exercises to the point whereby further movement is impossible could cause the spine to flex and result in a lower back injury. In this instance it is best to reserve 1-2 repetitions short of muscular fatigue or, at least, 'pre-exhaust' the muscles first, by way of leg extensions and leg presses before the squat, for example. By doing so, less weight can be used in the squat and the thighs likely will fatigue (and will reach failure) long before the low back muscles. More will be said about pre-exhaustion in Chapter 5.



Obviously, the amount of mental and physical effort alters from one moment to the next. Consequently, in order to think of intensity as a concept, it is necessary to do so within a moment or frame in time. For example, think of a set of exercise that comprises of lifting 100 pounds ten times. The first repetition would not be very intense, whereas the fourth repetition would be somewhat intense and the final repetition, when a person can barely make the lift, would be very intense. Of course, how hard or intense each repetition feels is a subjective experience since some people can tolerate exercise discomfort better than other people. But these subjective experiences can be quantified objectively with experience. What I mean is, as a person continues to exercise over the course of weeks, months and years, he or she can learn what it feels like to exercise hard. And the intensity of exercise at any time, from the beginning of a set or middle of a set can be related accordingly. Therefore, although it would be impossible to suggest that 37% effort was being produced "now," a person can say that the effort is a "4" on a scale of 10.

As with any aspect in life, each moment of effort in exercise is influenced or governed by previous moments, with all moments making up a continuous flow over time (see diagram below). In weight training, this influence is obvious, as effort becomes more extreme from each second or repetition to the next. Twenty percent effort of all available mental and physical resources may be all that is required to complete the first lift, then 35% on the second repetition, 50% by the third repetition, etc.



The Aerobic Industry & Intensity

Referring to the amount of effort produced as "intensity" is not just for weight training. The aerobic exercise industry refers to intensity as “physical effort,” measured by how high heart rate increases as a consequence of muscular exertion. Endurance-based exercise is further measured in a more scientific manner using Watts, with a "Watt unit" being equivalent to one unit of power, i.e., 1 joule per second.

Intensity of effort, relative to time, indicates the extent of functional loss as a result of exercise. This means that the harder a person exercises, the greater and faster the strain experienced by the mind and body. Consider how quickly a person "runs out of steam" after a 100-meter sprint (high intensity) as opposed to a 25-mile jog (low intensity). Consequently, there needs to be a balance between effort and time, since too great an effort reduces work time so much that a cardiovascular effect cannot be achieved. Conversely, if the effort is too low, then exercise becomes too easy and extended, and optimum health or fitness benefits are harder to achieve. This is why heart rate measures (intensity of effort) were established in the aerobic industry, to recommend how hard one should exercise (how fast the heart should beat) during activity in order to achieve adaptive health benefits, e.g., neither too little nor too much intensity of effort.

Similarly, strength training and bodybuilding must incorporate sufficient volume (sets) and frequency, and the extent of those aspects are relative to the intensity of effort. When exercising to build strength and muscle, the effort must be higher than what it is for endurance-aerobic exercise and great enough to make exercise *anaerobically* demanding and to 'force' the body to adapt with larger and stronger muscles (something that cannot be done with lackluster effort).

Borg's Perceived Exertion Scales

Another *industry standard* is the Borg Perceived Exertion and Pain Scales, as formulated by researcher Gunnar Borg. The study of psycho-physics is the scientific field that deals with the measure of sensory perception; or the physics behind that which we perceive and feel. Borg established scales of exertion (similar to the scales at the bottom of page 60 of this book), and these scales were designed to reflect the perception of exertion from his many test subjects. These scales took into account several aspects, including local muscle fatigue and breathlessness. The greater the mental and physical strain, the greater the rating on the Borg scale of exertion. In other words, the greater the demands of exercise, the higher the overall perceived exertion.

Do note that perceived exertion or intensity of effort may not be related directly to how much weight is lifted, i.e., the "heaviness" of the weight, but *how* the weight is used. A much heavier weight for a few repetitions, whereas six reps may be possible, does not place the same burden of mental and physical demands (perceived exertion) as a slightly lighter weight that is lifted to muscular fatigue.

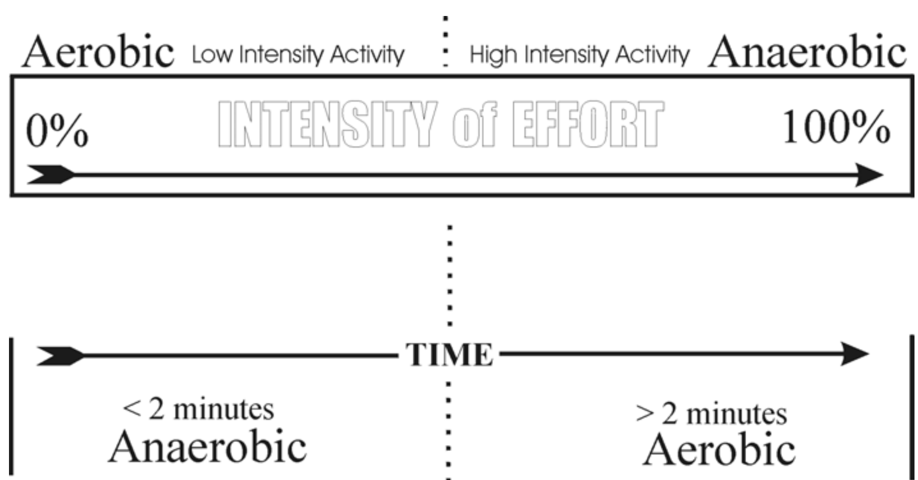
The reader may be confused or quite not understand why a lighter weight can be more intense to lift than a heavier weight, and so allow me to explain. Suppose a trainee performed *only one* lift with <u>90%</u> of a maximum weight (whereas 6 repetitions are possible), and then with <u>85%</u> of a maximum weight he performed eight repetitions to muscular fatigue (he could not budge the weight for a ninth repetition, no matter how hard he tried). What would seem bizarre is if the trainee declared the first set with greater tension (more weight) was more mentally and physically intense or demanding; yet, in the second set, he struggled with the weight and after the set he briefly felt physically incapacitated because of the extreme effort. A contradiction should be obvious, in that a heavier weight does not mean a need for a greater intensity of effort.

Also consider when you had to lift a heavy object once in comparison to when you had to carry something a bit lighter, such as furniture up several flights of stairs; the overall effort of the second task is much greater. On this basis, the weight should not be a factor in defining the word intensity, i.e., "a heavier weight is more intense." Rather, how the weight *is used*, or its *nature* within the grand scheme of things (in the context of the set or workout) is most important. Because of this, a person can make the same weight feel more intense by *how* the weight is used, and it is not always necessary to increase the weight in order to challenge the body to a higher level.

Aerobic & Anaerobic Activities' Relationship to Intensity of Effort

The terms aerobic and anaerobic refer to energy systems. Generally, the greater the effort, the more the activity reflects an anaerobic environment because of a very short time in which great effort can be sustained. This does not mean oxygen is not present during anaerobic energy production, but that the amount of oxygen is inconsequential to anaerobic (high effort) peak performance. Conversely, the lower the intensity, the more activity generally reflects an aerobic environment because of a longer time in which a lower level of effort can be sustained.

Below are two continua that reflect this relationship. The top continuum indicates that the greater the effort put forth, to a point of 100% mental and physical effort, the greater the level of intensity. The bottom continuum depicts effort relative to time, in that being able to tolerate exercise demands for two or more continuous minutes better reflects an aerobic (and typically lower intensity) environment.



As intensity increases, stress becomes less tolerable, and repercussions magnify...

Stressor	Low Intensity	Moderate Intensity	High Intensity
Heat (Touch Perception)	warm water (perceived warming of the skin)	hot water (retraction of body part to avoid pain)	boiling water (burn)
Light (Optical Perception)	candle (constricted pupils)	bright light (squinting)	Sun (temporary blindness)
Sound (Auditory Perception)	whisper (ear drum vibration)	rock concert (temporary loss of full hearing)	sonic blast (deafness)
Precipitation (environmental)	Sun shower (wet ground)	heavy rain (increased mud, waterlogged terrain)	flood
Poison	nausea	Severe illness	death
Force	bumping into an object (slight pain and/or bruise)	dropping a 10-pound barbell plate on your foot (broken toe)	being struck over the head with a sledge hammer (loss of consciousness or life)
Exercise	first repetition of a 10-repetition set to momentary muscular fatigue, or the ability to sustain sub-maximal contractions for several minutes	middle (5-7) repetitions into a 10-repetition set (increased FT response; labored breathing begins, greater perceived exertion)	final 1-2 repetitions in a set of exercise carried to momentary muscular fatigue, inability to sustain further contractions

Just as the other factors in the above table necessitate brief exposure as their intensities increase, the same is true of exercise. Evidently, anaerobic exercise is the opposite of aerobic exercise; they are two different types of activity that produce different effects on the body, i.e., the body adapts differently to each type of activity. Therefore, in regard to maximizing muscle strength and size, the following can be presumed with absolute certainty based on empirical evidence:

- If *low to moderate intensity* exercise developed abnormally high levels of strength and lean muscle tissue, long distance runners, aerobics instructors, and laborers would also be the strongest and best developed physically. This does not reflect reality.
- If *aerobic* activity developed abnormally high levels of strength and lean muscle tissue, the above individuals would, again, be the strongest and best developed. This is not the case.
- Consequently, high-intensity effort within an *anaerobic* environment must be the key factor in stimulating a maximum response for strength and muscle growth. And because effort is high, exposure to such a strain must be brief and infrequent in order to make minimal inroads into the body's recovery ability and to allow time for recovery and improvement in function (physical adaptation) to occur. Any exposure over and above the *ideal* amount necessary to produce an *optimum* response will produce an over-stimulus, and this increases the risk of overtraining, or doing so produces sub-optimal results at best. Therefore, volume and frequency should be low relative to a high intensity of effort when attempting to optimize muscular (body composition) change in the body.

The Nature of Intensity

Intensity of effort is a basic component required in any exercise program to stimulate physical change – the higher the effort, the better (but within reason and relative to a person's ability to recover, and how much volume and frequency is being performed). This should seem apparent if we consider that *some* effort – regardless of the magnitude or degree – is necessary to stimulate growth.[1] Without effort, there can be no disruption or agitation of the muscles' current function, and there would be no reason for muscles to become stronger or more resilient. Consider sitting all day, just waiting to stimulate growth as a result of "near zero" effort; it won't happen. Rather, to stimulate the muscles to become larger and stronger, an unusually high and intense effort is necessary, combined with a *sufficient* amount of volume and frequency.

Depending on a person's exercise experience and physical status, training to the point of muscular fatigue – wherein another repetition in good form is impossible – may be unnecessary to promote further change in the body. But the higher the intensity, the greater the agitation… and the more probable will there be a muscular change.

Fundamentally, someone new to exercise will not require very intense exercise to produce results. The strain of exercise is so new to the body that any amount of effort and regular activity will bring about changes. For a person with several weeks or months, or a few years experience, the quality and extent of intensity of effort will need to increase, and this increase may require that both volume and frequency reduce. In this regard, *quality* replaces *quantity*.

Reducing volume and frequency is an important consideration for the advanced exercise enthusiast. Performing more and more exercise is rarely the solution, and doing so is often the cause of poor results or the loss of strength. After a few years of exercise, and if the goal is to continue improving, it is necessary to exercise "hard" in order to stimulate further strength and muscle gains. Even long distance runners, people who focus on endurance training, must run "harder" in order to complete a 25-mile run in <u>less time</u>. *Hard training* is defined as <u>challenging exercise demands that are both *ideal* for the individual in question and *sufficient* in measure to reduce the extent of functional loss, to maintain function, or to produce further gains in function, relative to one's genetic ability and goals</u>.

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[1] Evidently, if 10 repetitions were performed, the tenth would be the most difficult (more intense than the ninth), and the ninth more difficult or intense than the eighth, etc. And, obviously, the closer a person approaches muscular fatigue, *when the weight can no longer be lifted in good form*, the more demanding each ensuing repetition becomes. Moreover, the greater the effort, relative to one's physical abilities and limitations, the less total work (set volume) one is capable of performing.

Intensity of effort on each ensuing repetition also varies in measure. At the beginning of a set there exists 100% of possible strength in reserve, of what is possible "at that time." After completing the first of ten repetitions, there is a loss of some strength. Continuing to the tenth and final repetition, more strength is lost, but in greater amounts, e.g., 10%, 22%, 38%, etc. In other words, as metabolic demands increase, so too will the reduction in overall strength – but NOT proportionately from repetition to repetition. This is true since fatigue and metabolic byproducts, from energy production and usage, increase the rate of fatigue we experience. This means that it takes greater effort to complete each ensuing repetition, while the ability to generate muscular effort decreases.

It should be noted that exercise that becomes “harder”, or is as hard as one can make it, does not always refer to "effort". Harder exercise can mean an increase in volume and frequency since those things, too, are part of "exercise demands." In this instance, a person can put forth the same amount of effort in each set, but perform more sets or exercise more often. But volume and frequency must be increased appropriately and sparingly to help a trainee out of a slump, such as increasing exercise demands to “shock” the muscles. However, to increase volume and frequency too much will cause a person to decrease the intensity of effort, a direction that is the opposite of what people should do. This is true whether the goal is to increase strength and muscle or even endurance. Again, marathon runners do not attempt to run further and further. Rather, they will condition themselves to particular distances and attempt to run those distances more quickly – thus exercising more intensely within a certain volume (distance).

Regularly attempting more repetitions with the same weight and/or using more weight for the same number of repetitions – the *progression/overload principle* – is another method to increase training demands, to make exercise harder. And adding weight or repetitions to exercises regularly eventually results in extreme effort (and a need to exercise to muscular fatigue). This is true since everything is finite, including human strength, which cannot continue to be challenged with more weight or more reps without, eventually, hitting a critical limit and necessitating all-out effort. Consider your own ability to lift, say, 50 pounds on an exercise machine for 12 repetitions. Very few people, if any, will be able to continue improving until the entire weight stack of 300 pounds (or whatever the weight) can be lifted for 12 repetitions without having to push themselves to the maximum... at least once in an exercise career.

The effect and nature of intensity can be exemplified if only one lift was performed, whereas ten repetitions are possible. If stopping at one lift, it would not be expected that growth or more strength in the muscles would be stimulated. Why should it since that one lift was so easy to complete? The same is true if 2, 3, or 4 repetitions of a 10-repetition set were performed, a level of effort that would do little more than maintain current strength levels at best. It is only when muscles approach muscular fatigue, when intensity of effort is high that muscles receive a "signal" to improve their function or resilience. It is this “difficulty” that signals the body that the effort was unusually strenuous, and in order for the muscles to protect themselves from future assaults of such great effort, they need to become larger and stronger. Once they become larger and stronger, they do not have to work as hard to complete the same amount of exercise. This explains why muscles become larger and stronger, and it also explains why increasing the weight or the number of repetitions with the same weight is beneficial to increase strength and muscle further. This is true, however, only if there is a corresponding and *sufficient* amount of volume and frequency present. Performing far too few sets of exercise, too infrequently, will not cause greater muscle growth even if a person exercises with 100% intensity of effort. Yet, there must be sufficient rest between exercise sessions so that the body has time to "heal" and become stronger and more muscular.

It then should be evident that the greatest quality of effort a person can produce – relative to individual ability – best guarantees growth stimulus. Increasing volume and frequency also produces greater "difficulty" but, as explained, these factors must be applied sparingly to limit *overuse injuries* (e.g., sore or achy joints), overuse atrophy, and to avoid having to reduce intensity to too low a level in order to tolerate the exercise session. Hence, there is a fine line between prescribing an appropriate or ideal balance of intensity, volume, and frequency and doing too much or too little.

Do note that training to muscular fatigue is no guarantee that strength and muscle growth will be stimulated. Many people who exercise very hard, and who still have potential to grow even more muscular, may not improve. This can be because of:

- Not enough or too much volume or frequency
- Becoming too adapted to the training demands (i.e., not altering the exercises and method of exercise often enough)
- Following a nutritionally inadequate or poor diet
- Not coordinating the strain of exercise with various biological cycles (e.g., women who train too hard during menstruation can become very fatigued)
- Insufficient mental capacity to sustain physical rigors long-term.

...or any other possible factor or combination of factors. Moreover, not everyone should or can exercise to muscular failure, as presented below.

Those Who Should <u>Not</u> Exercise to Muscular Fatigue

Exercising to the point of muscular fatigue is not easy. It takes a considerable amount of mental (motivational) and physical effort, sometimes exceeding how hard most people are willing to work (and often because they do not understand how to exercise hard or are not motivated by a qualified instructor). Consequently, there may be instances whereby maximum effort training is not warranted. They include:

1. **Beginner trainees**, whose focus should be on learning proper mechanics, breathing, and mental focus, i.e., learning to isolate the worked muscles. Moreover, most beginners lack the mental skills to exercise to muscular fatigue, and they likely will not be able to train very hard anyway or know how to do so without some practice in that direction.

2. Those requiring a reduction in training demands **to accommodate recovery or mental strain**, since training "very hard" is more demanding mentally than training "somewhat hard", and periods of less demanding exercise is an effective method to help maintain motivation to exercising hard most of the time and for several years.

3. Trainees who must work through the initial stages of soft tissue **injury rehabilitation** should avoid maximum effort exercise. The focus should be on achieving normal range of movement, proper form, and learning to "get over the hurdle" and adapt to any pain associated with normal movement. Also, training to muscular fatigue likely would be too painful for most people trying to recover from an injury unless negative-only based exercise is implemented.

4. Those with **special conditions** that preclude them from exerting and fatiguing the muscles to extremes, particularly nervous conditions such as spinal muscular atrophy and injury, post-polio syndrome, and Lou Gehrig's disease. There are many other conditions that must be considered, such as heart attack rehabilitation. These individuals would fare better with slightly higher volume and frequency and lower intensity, to sustain a manageable heart rate for longer periods, to enhance overall conditioning, rather than focusing on maximizing strength and muscle mass. Pushing the limits of intensity of effort may also place a dangerous and unnecessary strain on the heart of those with heart conditions. An individual with a special condition should seek professional advice from his or her physician before starting any fitness program.

5. The **elderly** need not perform to-fatigue exercise, unless they enjoy the challenge. The magnitude of muscular growth and strength diminishes past age 50, and training with maximum effort will not produce much more benefit than exercising with "good" effort. With the elderly, usual goals include an increase in functional ability (range of movement and strength) and a reduction of fat stores (and possibly the correction of minor injuries or poor body mechanics). Senior exercise is less about maximizing physical appearance and transformation – goals often attempted and valued by their younger counterparts. However, the fact remains that the higher the intensity of effort, the less frequently one needs to train and for briefer workouts, a factor that will interest many older individuals.

6. Those who simply **do not enjoy training to muscular fatigue**, and who are uninterested in obtaining optimum results (most people are happy with 'good' results relative to their abilities), would fare better with slightly higher volume and frequency and reduced intensity of effort. This would ensure compliance to a regular exercise program by accommodating the individual's mental status, i.e., preferences. However, proper motivation and explanation of the outcomes with a proper high-intensity workout can encourage people who otherwise would not exercise in that manner.

7. **Athletes** who train intensely outside the weight room should avoid to-fatigue exercise, or include it cautiously and sparingly. Athletes who must focus optimum attention, time and effort on sport-specific activities must be careful to avoid overuse or taking too long to recover between very intense workouts. Being too fatigued or having extreme muscle soreness from very intense exercise also can interfere with proper movement of sport specific skills. In these instances, stopping short of muscular fatigue by 1-2 repetitions, but still exerting sufficient effort to maintain gains produced through previous and more intense

workouts, may be more appropriate when focus is on sport skills; whereas, to-fatigue training is encouraged greatly during the off-season. However, this will depend on the nature and extent of exercise within sport specific training and competition, as well as the tolerance of the athlete.

Importance of Sub-fatigue Exercise

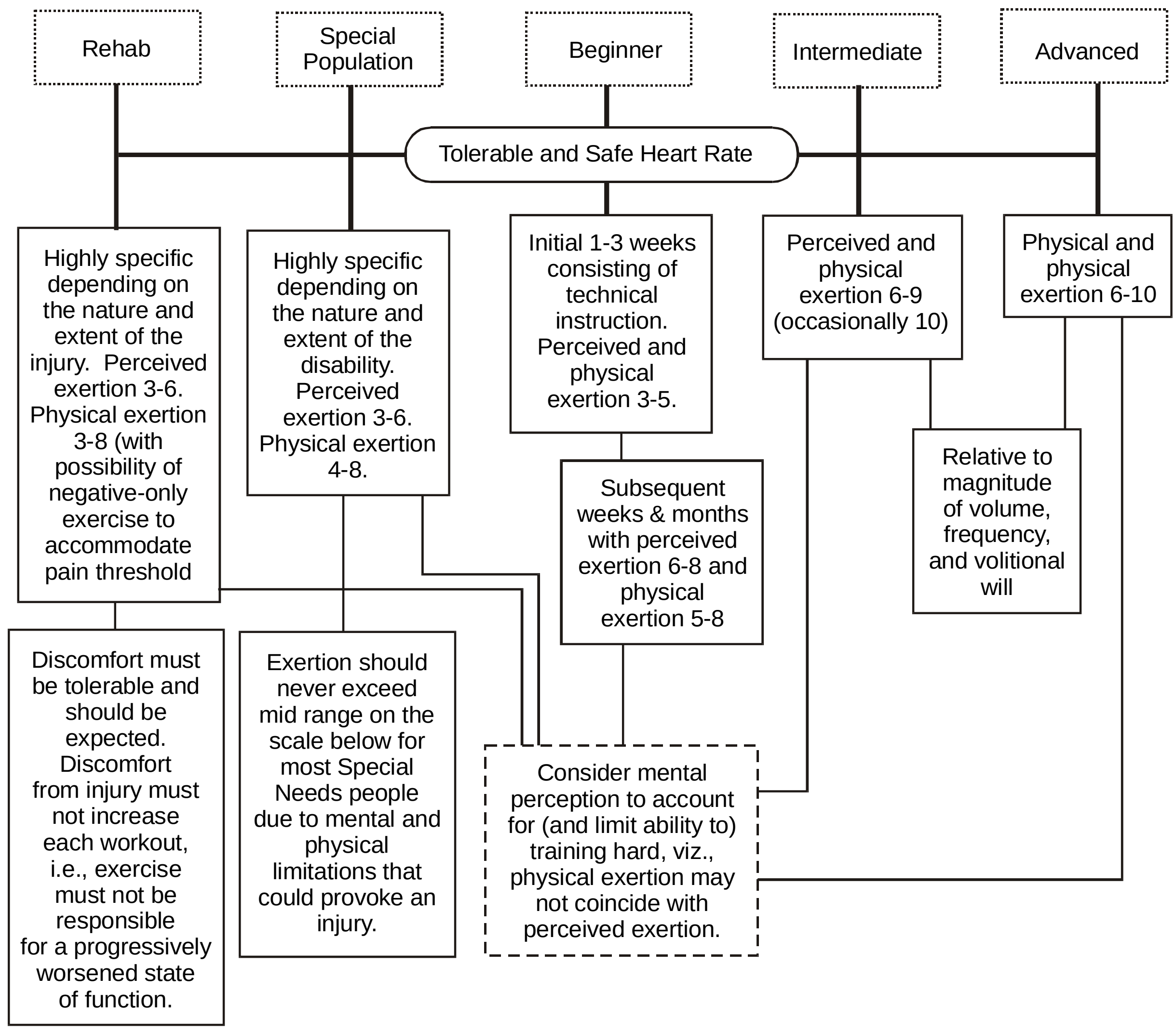
It is demanding mentally to exercise with maximum intensity every workout, regardless of any potential physical benefit. It can be devastating motivationally having to improve each and every time and to exert one's self to the maximum in order to make those improvements – particularly within a training career that spans several decades. Moreover, no one can make steady gains indefinitely – especially if a trainee has at least 2-3 years of serious exercise experience. Nor would it be expected of a 60-year old man to better accomplishments achieved 10 years previous. If a trainee could make gains every workout for the rest of his or her life, that person would be sporting a world-champion physique and would have super-human strength. It simply will not happen, and reality needs to take root when designing a long-term and appropriate high-intensity program for a trainee at any level.

Empirical evidence indicates that training to muscular fatigue often, but not necessarily all the time and if balanced properly with volume and frequency, is the fastest way to realize goals. This becomes more apparent as a person becomes stronger and more muscular. Increased strength and size places greater demands on the body because of the heavier weights lifted, as well as the energy requirements to move those heavier weights and for adequate recovery between workouts. These factors make to-fatigue training more demanding later in a person's exercise career than at the beginning of an exercise career.

There are still ways to train hard, but in a "cyclic" or rotational approach. One recommendation is to duplicate or triplicate workout accomplishments before attempting a new personal best record – and *not* to feel guilty in the process, thinking that progress must occur in every workout. However, if the trainee desires to progress more frequently, and is capable of doing so, that preference should not be ignored. Another approach is to perform sub-fatigue exercise for 2-3 weeks followed by to-fatigue exercise for a week or any other pattern to the liking and tolerance of a trainee. Or sub-fatigue exercise can be alternated or included every 3-4 sessions; the possibilities are many.

On the following page is a flow chart that describes and recommends how to measure and prescribe intensity of effort and perceived effort.

Determining Appropriate Intensity



Perceived Exertion Scale

(Relative to either or both weight load and/or discomfort due to fatigue or injury)

1. No effort
2. Very easy
3. Easy
4. Somewhat easy, but tolerable
5. Somewhat difficult, but tolerable
6. Difficult, but tolerable
7. Very difficult, but tolerable
8. Extremely difficult, but tolerable
9. Extremely difficult and hard to tolerate
10. Extremely difficult and cannot tolerate at all or very infrequently

Physical Exertion Scale

1. No effort
2. Very low effort
3. Low effort
4. Low to moderate effort
5. Moderate effort
6. Stop short > 1 rep to muscular failure
7. Stop short 1 rep to muscular failure
8. Train to muscular failure
9. Muscular failure with training variables that do not extend beyond muscular failure, e.g., stutter repetitions
10. Beyond muscular failure with training variables, e.g., forced and negative reps

A HIT Warning About Too Little Exercise

Consolidation Training and Disuse Atrophy

If "too much" exists, then "too little" must exist. Under the direction of Dr. Robert Kudlak, M.D., I assisted in the operation of BackWorx, a MedX low back rehabilitation clinic. Although not injured, I began performing one work set per week for a tension time of about 90 seconds to see if the machine could increase the function of my spinal erectors, beyond their current ability. After a few months, my lower back strength was *less* than it was before using the specialized equipment. I continued for another few months, and the situation worsened. I then reduced frequency to once every two weeks, then eventually once every three weeks. At that point my strength improved somewhat and finally returned to my pre-testing levels.

It was not until I further reduced the frequency of this machine exercise, to once every four weeks, that my low back strength began to improve beyond pre-training levels. Unfortunately, when I began improving well, the clinic moved to a different city in Ontario, Canada, and I no longer had access to the equipment.

Now, it is important to understand what happened. <u>Low back muscles take much longer to recover than other muscles</u>, since the low back is constantly under tension during every waking hour of the day, and those muscle fibers perpetually fire to keep the torso in an upright position. Couple in the factor that I included bent rows and squats in my exercise regimen and it could be understood that I was providing an unwavering training stimulus from which to recover.

But a bad situation can be made worse. The MedX Lumbar machine is *so specific*, and the demands so concentrated (since the remainder of the body is highly restrained) that it takes several days or weeks to recover fully – particularly if one exercises to a point of muscular fatigue. Most of our patients underwent only one weekly treatment of one work set. But as Arthur Jones recommended in his book *The Lumbar Spine, the Cervical Spine, and the Knee: Testing and Rehabilitation*, "*Some few subjects will not make gains in strength if exercised more frequently than once every third week. And subjects that do best on a schedule of one exercise every second week are common; are usually subjects with a high percentage of fast-twitch fibers*" (p. 55).

Of course he was referring to the low back under the strain of his highly specialized machine and NOT to every muscle group in the body exercising under typical conditions with conventional equipment.

Yet it has come to a point whereat some people have followed this advice universally and have reduced training volume and frequency to such an extent that although they regularly increase strength (lifting ability), their muscles are atrophying because of an insufficient volume and frequency stimulus. The group that has reported the greatest loss from disuse atrophy include those who have followed such advice, from Mr. Universe, Mike Mentzer.[26] Besides a slow loss in muscle mass, their cardiovascular and cardiorespiratory systems likewise deconditioned, but at a more rapid pace. The "less is more" group believes that volume and frequency be reduced since the larger and stronger the body becomes, the less it can tolerate high quality effort exercise, and this is true – but within reason.

However, this group will usually not train often enough or long enough (viz., sets) to maximize muscle mass or metabolic conditioning, yet will conclude improvement is being made as a result of a false positive reading of strength increases. Fundamentally, it takes far less activity to maintain or increase lifting proficiency (i.e., the ability to lift progressively heavier weight in select exercises) than to maintain or increase lean mass and cardiovascular functioning. On this erroneous basis, it is postulated that so long as "strength" increases regularly, muscle mass also must be increasing, or at least it will show improvement "eventually". In effect, it is believed that performing only one set of an exercise for each muscle group to fatigue, and if that one set increases in overload to "some" measure, then everything necessary to stimulate growth would have been done. But this is not *always* the case.

From empirical evidence gathered on my part, a constant reduction in activity can be carried to extremes, resulting in a progressive "strength" increase with a *corresponding decrease* in lean mass. Volume and frequency *do* have some influence in maintaining and maximizing muscle mass; intensity of effort and progressive overload are not the only factors to be considered. It is the totality of the exercise demands – their synergy – that governs exercise results. There are several reasons why not exercising frequently enough, or for enough sets can result in reduced conditioning and loss of function.

First, exercising too infrequently alters the balance between localized and systemic recovery (see chart below). Training very hard does necessitate training very infrequently relative to individual ability and set volume prescription. And since muscles recover much faster on their own than the body as a whole (because of the constant barrage of localized strain from all the muscles), training very intensely all the time, in a split routine, may result in the inability of the endocrine, lymphatic and nervous systems to recover sufficiently before a muscle begins to atrophy before its next workout. At least this can be true over the long-term, which is why periodic layoffs are beneficial.

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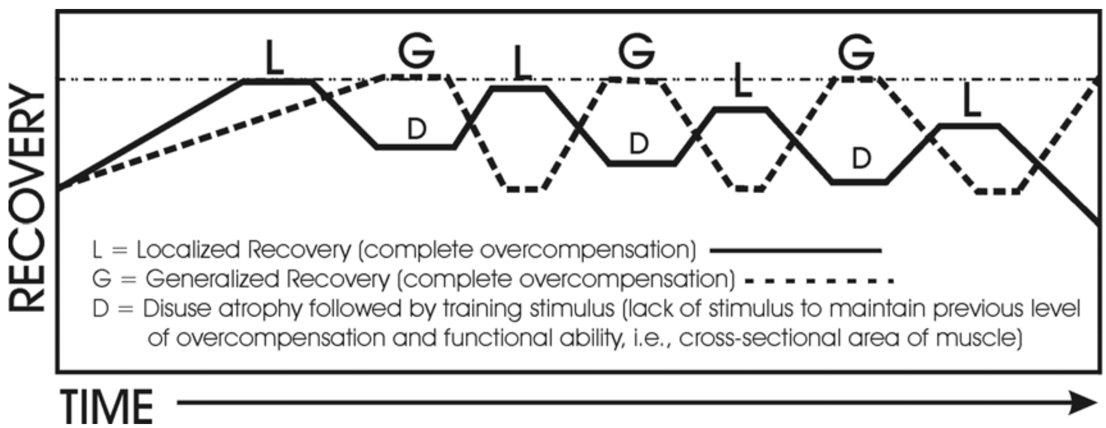
[26] In his book *Heavy Duty II: Mind and Body*, Mike Mentzer has recommended using as few as three exercises every 6-7 days, with each exercise repeating no more than once every 12-14 days for no more than one set each (p. 130). He is the first to recommend the "benefit" of consolidation training, of performing as few exercises as possible to work all the major muscle groups of the body, such as squats, deadlifts, dips, and pulldowns to stimulate the lower body, back, chest, shoulders, and arms.

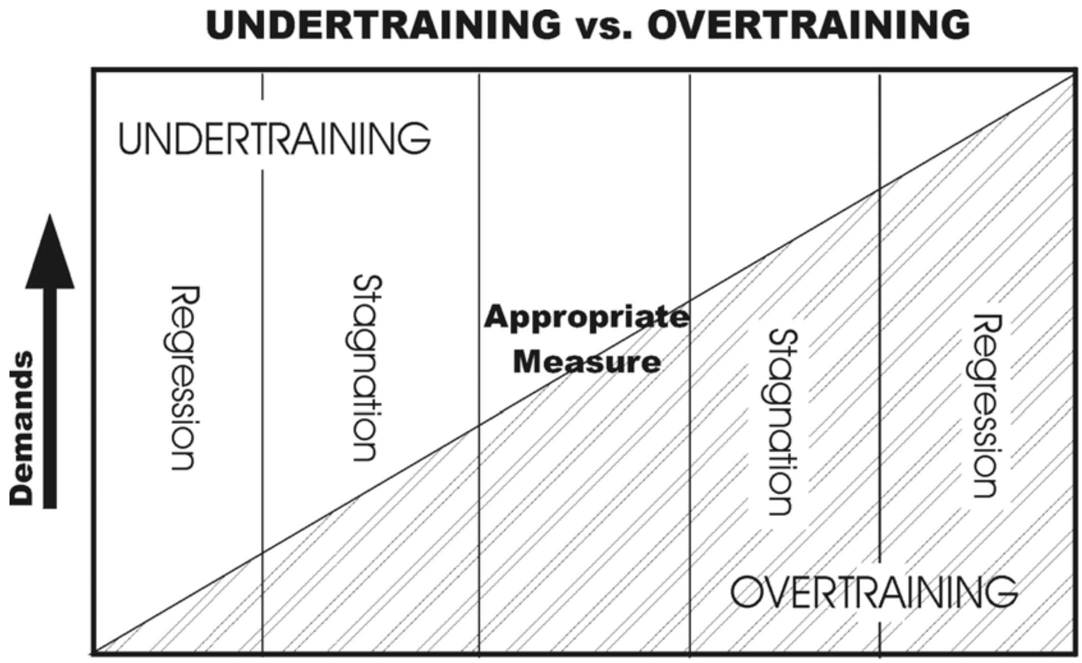
It also appears that the nervous system takes as long or longer to recover than the endocrine system, because of the depletion of neurotransmitters at the presynaptic end of the neuromuscular junction. This is one reason why it is appropriate to alternate or cycle different measures of intensity and total training demands.

It has been speculated by some authorities that a muscle can retain its strength (and possibly size) for 21-28 days without further exposure to exercise strain. This appears to be true, having experienced it first hand, but that does not mean it is ideal to avoid exercising a muscle for that length of time on a regular basis if progress is desired. Rather, that guideline refers to the *maximum* delay *before* atrophy and anaerobic deconditioning begin in most (non-hospitalized and immobile) people. But if exercised too infrequently, the body adapts toward a need to reduce function (homeostasis) to correspond to the new standard of survival requirements.



Regarding volume, performing 1-2 very intense sets, particularly if including set variables (e.g., forced repetitions), adapts the body to that environment and to those demands. Consequently, performing 1-2 traditional sets sub-failure or even to-failure may be enough only to maintain the gains produced under the more demanding set criteria that included set variables. Hence, if a person performs 1-2 sets with set variables, it may be necessary to increase the demands to 2-4 "regular" sets on other training days. Once set variables are reinstated, the volume can decrease accordingly. It should be apparent that trainees are balancing more than intensity, volume, and frequency, i.e., <u>the demands (nature of the workout) as a whole</u>, including the magnitude of inroad as a result of set variables.

The catch-22 of constantly decreasing volume and frequency is that the more the total workout demands decrease, and the more the body loses functional ability from lack of activity, the more demanding each workout feels. This means experiencing greater levels of fatigue during and after a set/workout and gradually greater systemic drain for days following a workout. Feeling progressively more fatigued, as a result, falsely indicates to the trainee (at least in this instance) that more recovery time and less volume should follow, since increasingly greater fatigue happens to be a symptom of overtraining. Ironically, many symptoms of overtraining *are also symptoms* of undertraining.



NOTE: What produces regression or stagnation from undertraining, or regression or stagnation from overtraining varies greatly, depending on short-term or long-term application. The magnitude of what consistutes short- or long-term application (i.e., days, weeks, months, or years), then alters the prescriptive needs of the measure in question.

The effects of disuse atrophy are not apparent immediately and it may take several months for the effects to be noticeable – when and if the trainee decides to scrutinize closely what has been happening. Also, the effects of disuse atrophy are most noticeable if the trainee's body fat stores are low enough to see muscular development and if standardized photographs are compared on a monthly basis. Accurate body composition analysis also will provide indication of what is happening in regard to fat and muscle ratios. This is an important biomarker in physique development since many who undertake consolidation training, or implement a vast reduction in activity, rarely reduce calorie intake, to match a reduced level of activity. Consequently, body fat stores can climb slowly, thus increasing overall body weight and possibly falsely indicate an increase in lean mass.

Exercise Tolerance

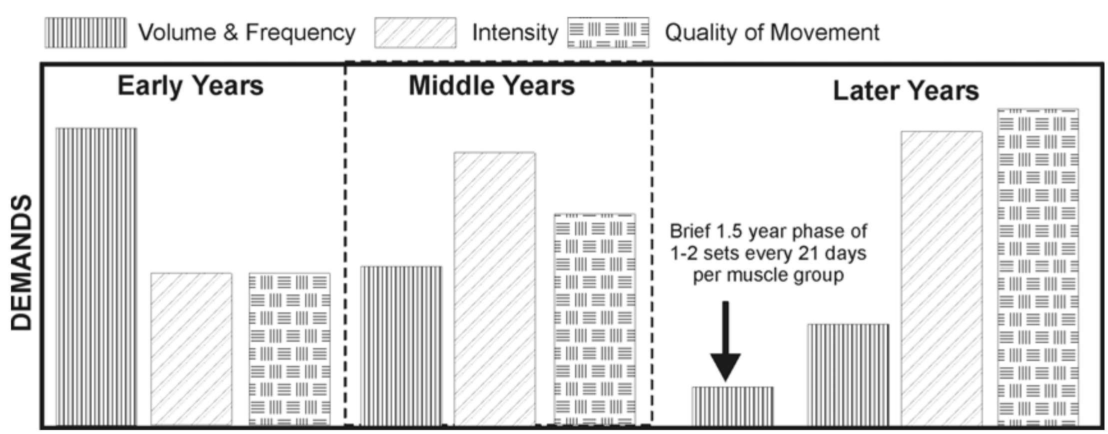
A basic tenet of physiology states: As people age certain physiological aspects transpire, such as lower testosterone and immunity levels. While these aging effects occur as a trainee attempts to improve upon or sustain muscle and strength, the less exercise a person will be able to tolerate – at least if the quality of effort remains relatively constant. Although true, how much less exercise is required? This is an important question and direction in exercise prescription since what a teenage boy can tolerate may be different from what he can tolerate when he is 25, 40, or 60 years of age. Consider my tolerable exercise demands over the course of two decades:

> *Early Years*: I exercised each muscle group twice per week for 10-12 sets each (and up to 20 sets per muscle on occasion; intensity was usually moderate, but sometimes to failure).
>
> *Middle Years*: I exercised each muscle once a week for 4-6 sets each (all sets to failure).
>
> *Middle-Late Years:* During the mid- to late-1990s, I slowly decreased volume and frequency to 1-2 sets every 21 days. I also looked and felt progressively worse (less energetic) from lack of activity – although my strength increased each and every workout with few exceptions and to levels not experienced before. It was this 'false-positive' of dramatic strength increases (from the continual practice of minimal exercise movements and vast recovery) that led me to believe that doing so little was in my best interests.
>
> *Later Years*: I exercised each muscle once every 14 days, with larger muscle groups having received 4-6 sets each, and smaller groups only 1-3 sets each. However, a reduction in volume (3 sets for larger muscles and 1-2 sets for smaller muscles) and an increase in frequency (each muscle trained every 7 days) have worked more effectively. A doubling of volume and frequency occurred for 2-3 week periods every 3-4 months to challenge function and ability optimally.

Because of my younger age and correspondingly less muscle mass, I tolerated a high volume approach during my mid- to late teen exercise years. I increased strength on most movements at least every third workout, and I did improve in appearance, albeit slowly, taking over ten years to add twenty-five pounds of lean tissue. Some of this growth would have been due to natural maturation and not exercise. Obviously my training was sub-optimal, but it did work to some degree. It was tolerated.

The training I performed during my middle years – when first embarking on a more abbreviated routine – resulted in a 100% reduction in both volume and frequency. I achieved my physical best about age 26 and 184 pounds. From that point, and up to age 34, I slowly decreased volume and frequency until I was performing only 1-2 sets every 21 days. I also looked and felt progressively worse (less energetic) from lack of activity – although my strength increased each and every workout with few exceptions.

Since 1999, my exercise regimen reinstated a slight reduction in volume of sets as performed during my “middle years”, and with a similar rate of frequency. (The rate of frequency of once per week accommodates the calendar and ease of implementation in regard to scheduling; once every 9-10 days is more appropriate for my recovery ability, but brief one-week layoffs now and again seems to work as effectively). This direction has reversed the deconditioning that took place from performing as few as 1-2 sets every 21 days, thereby allowing me to regain lost size, then gain an additional six pounds lean mass. Obviously I needed to reduce exercise demands to some measure, as compared to my teen years, to accommodate my aging and the metabolic demands of having larger and stronger muscles, but not to the extent that I had thought was necessary.



In sum, my total volume and frequency were reduced about 100% between my early and middle years, then another 50% from my middle to later years. Further, it should be noted that the quality of effort and movement has vastly improved since my earlier years, and that has a significant bearing on volume and frequency. Consequently, if 10-12 sets of fairly hard exercise under lower quality conditions were compared to 3-4 sets of greater concentration/effort and superior lifting form, my tolerance has not reduced all that much. Bear in mind, however, that comparisons are being made between a teenage boy and a 40-year old male, and not that same male aged 50 or 60. More apparent differences in exercise tolerance do exist when individuals enter a change of life, i.e., hormone fluctuations.

Chapter 3

Quality of Movement and Proper Breathing

Hard training necessitates sufficient muscle loading. This means moving ‘slow enough’ to maintain tension on the working muscles throughout the exercise’s intended range of motion, with minimal momentum. This is important to realize since the faster a person moves, particularly if implementing explosive or ballistic action, the more the muscle unloads as the weight is thrown or propelled. If this happens, a few sets for a muscle will not feel or be very effective. However, by moving slowly and reaching a point of muscular fatigue, a few sets will feel very exhausting and the stimulus for improvement possible.

Repetition Velocity, Time, and Cadence

Velocity refers to speed + direction. **Speed** refers to the distance traveled by a body per unit time. **Time** provides a measurement of a period during which an action, process or condition exists or continues to exist. Together, distance and time provide the basis for an exercise’s **cadence**, the beat, rate, or measure of any rhythmic movement. Two common cadences include the Nautilus protocol of 2 seconds on the positive and 4 seconds on the negative, and the Superslow® protocol of 10 seconds on the positive and 5-10 seconds on the negative.

The primary mistake made by fixing a particular cadence for all exercises is that doing so does not account for the variations in the range of motion or distance among exercises. For example, a wrist curl covers a much shorter distance than a triceps extension, which covers a shorter distance than a lat pulldown. In order to accommodate a fixed cadence, e.g., 2/4 or 10/5, a trainee must significantly alter the velocity of exercises that have substantially different ranges of motion (see example below). Alternatively, if one were to maintain the same relative velocity from exercise to exercise, whatever that velocity may be, the time taken to cover varying distances will change, thereby resulting in varying cadences throughout a broad spectrum of exercises. Hence, exercises with short distances will take a briefer time to complete than medium or longer distance exercises if moving at relatively the same velocity.

Altering Velocity to Accommodate a Fixed Cadence

Abdominal Crunch	Triceps Extension	Underhand Lat Pulldown
Short ROM	Moderate ROM	Long ROM
If cadence = 5 seconds, then velocity = **X** to accommodate 5 seconds	If cadence = 5 seconds, then velocity = **Y** to accommodate 5 seconds	If cadence = 5 seconds, then velocity = **Z** to accommodate 5 seconds

Moreover, the stroke difference between short and tall individuals can be quite dramatic. Compare someone who is five feet tall to someone who is over six feet tall, or to someone who is seven feet tall. If five seconds were an ideal time for the 5-foot person to lift a weight in the lat pulldown, for example, how or why would five seconds be ideal for the 7-foot basketball player?

The ideal cadence, as with any aspect of an exercise program, must be prescribed individually, with each exercise's time being reflective of limb length, range of motion, and even neurological efficiency. In regard to the latter aspect, some people have difficulty moving very slowly without segmenting repetitions in a jerky manner. If a personal trainer or fitness enthusiast wanted to maintain a fixed cadence, I have found that for most people, on average, a cadence of 5-5 is appropriate. It is slow enough, but not too slow (unnecessarily slow), and appropriate enough to accommodate most exercises for the major muscles. It also is a convenient cadence for data tracking, since one repetition equals 10 seconds, and so if a tension time of 60 seconds is desired, then six repetitions would be the goal.

Discovering Appropriate Cadences

First, the weight must move properly. This means sound biomechanics, slow motion (slow enough to avoid injury) and controlled tension. Hence, when lifting a weight, a trainee should at first generate only enough muscular force to initiate motion of the weight, as if to *squeeze* into the initial few inches. From that point, only enough force should be produced to keep the weight moving <u>slowly</u> and <u>smoothly</u> while the rate of acceleration remains limited. Once at the top, i.e., the exercise's most contracted position, a brief half-second or full second pause may be instituted, followed by a deliberate and controlled reversal in direction. If the exercise offers an intense contraction, such as with the calf raise, then the top position can be held longer to increase muscle inroading, with 2-3 seconds being reasonable. The slowness of the eccentric phase need not be exaggerated unless that is the intention. The goal simply is to lower the weight under control and <u>ease</u> the weight into the bottom, stretch position.

If movement does not appear to be both slow and smooth (particularly smooth) by following a particular cadence protocol, whether 2-4, 4-4, 5-8, etc., then the speed of movement must be reduced.

Two words must be defined at this juncture: smooth and slow. **Smooth** means of uniform consistency, without abrupt jerking or stopping. **Slow** refers to a velocity that permits such smooth movement. Consequently, explosive movements are not slow since the action begins with an abrupt start, and if continued quickly, results in an abrupt stop at the top of the movement. Likewise, dropping a weight quickly to the bottom position is neither smooth nor slow since it, likewise, results in an abrupt stop. Ballistic movements, e.g., those resulting in bouncing with stored energy torque helping to rebound the weight upwards, is neither slow nor smooth. Further, both explosive and ballistic training methods increase the risk of injury because of the increased forces and should be avoided. **RULE**: Velocity (and cadence) must be slow enough to experience and perceivably control every inch of the range of motion without jerking, dropping or bouncing the resistance, yet not much slower.

Accuracy in Tracking Repetition Cadence

There is a reason for keeping exercise cadence (in general or for a particular exercise) consistent: By tracking repetition cadence, with some accuracy, the progress and overall value of a program can be determined. For example, consider a trainee utilizing varying rep cadences within the same set, and that he happens to stall on the 8th positive rep of a set, completing only seven repetitions to muscular failure for 60 seconds *Time Under Tension* (TUT). Next, consider that the trainee were to lift and lower the weight slightly faster in the following workout, completing eight positive repetitions to muscular failure, again in 60 seconds TUT, then ended the set with one last negative repetition for a total of 67 seconds TUT. By his records, the latter set appears to be an improvement since he added an additional repetition and endured seven additional seconds with the same resistance. However, the problem is that both workouts are not similar in structure; they use different cadences, and they cannot, therefore, be compared ideally.

In another example, if a trainee performed 10 repetitions with 100 pounds one workout, with a TUT of 60 seconds, then in the following workout performed 11 repetitions with 100 pounds, with a TUT of 66 seconds, then it can be deduced that the trainee improved. However, if the TUT remained at 60 seconds, yet the repetitions increased from 10 to 11, could it be said that improvement did, in fact, occur? Metabolically, performing more repetitions in the same period of time is different from performing fewer repetitions in the same time.

One could argue either that:

a) The trainee did not improve – since the tension time did not improve, or

b) The trainee did improve – since the number of repetitions increased.

If argued that he did improve, it is difficult to measure to what extent this is true, since the units of measurement (repetition cadence) altered from one instance to another.

To make the issue more complex, a 2-second positive is less demanding than a 5-second positive with the same weight, even if one were to aim for the same Time Under Tension (obviously the *number of repetitions* will vary accordingly, to accommodate the TUT). This occurs since there is greater momentum with the faster velocity. And by not tracking and standardizing the cadence, a trainee may unintentionally expose the muscle to *less* tension and inroad, thereby making the set *easier* with a slightly faster velocity.

Conversely, moving too slowly on the negative phase, slower than usual or that which is prescribed ideally as an individual's benchmark, makes work *less* demanding. Since lowering a weight is far easier than lifting a weight, taking an additional 2-3 seconds for the eccentric phase affords repose, possibly allowing for sufficient laxity between repetitions to permit an additional positive repetition on the final up-stroke.

Moreover, the capacity to improve regularly in repetitions is affected by the cadence and ROM of the exercise. For example, if a trainee were to use the same weight, it may take a few workouts to increase by one repetition if the benchmark is a 10-second positive phase. On the other hand, only one workout may be required to add a repetition if it took 4-5 seconds to complete each repetition. For this reason a person should not move too slow.

In summation, to make precise comparisons, workouts must be regulated and standardized by utilizing *equal units of measurement*. This is not to say that one must measure everything, including repetition cadence to establish an effective program, but doing so increases accuracy – an often lacking commodity in exercise research and practice.

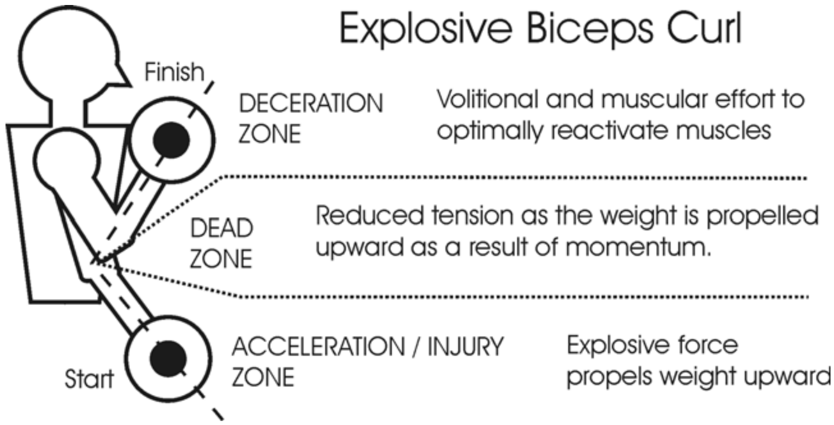
Movement Velocity

As velocity increases, the magnitude of **impulse** (the signal that travels along the length of a nerve fiber and is the means by which information is transmitted through the nervous system) to move a limb must increase. This means a greater firing of motor units that activate a greater number of muscle fibers.

Moving too quickly, however, increases the risk for injury, because of high forces. Moving too quickly, as with explosive movement, also increases **momentum** (mass x velocity), to the point wherein muscles incur the most force during the initial few inches, but less tension as the weight is propelled upward because of the initial thrust (see diagram on next page).

Strength and size increases are dependent on three aspects, whose quality and relationship remain interconnected for optimal inroading:

1. Intensity (effort)
2. Metabolic work (time relative to the effort and strain)
3. Tension (strain)



Also, allowing the weight to bounce in the stretched position reduces muscular tension since the CNS reduces signals to perform work. Thus, muscle fibers need not work as hard to complete the same task. Observing biomechanics of daily activities explains this phenomenon. People do not walk, do gardening, or other household chores ultra slowly – nor do we rush or throw things about. Rather, we move at a comfortable pace that allows us to generate the least energy possible to complete a task. This "pace" results in a small measure of bouncing, hitching, or jerking that excites muscle spindles. In effect, most activities are done with some bouncing, albeit fairly low in force compared to what is advocated in the exercise industry.

The "rebound" reflex reduces the central motor command required to achieve a given tension, allowing muscles to work less than when moving very slowly. Less muscular work means less muscular tension and inroading, and that is why those who exercise ballistically can train for longer periods of time than those who train slowly with no bouncing.

The benefit of moving slowly (at least "slowly enough"), as opposed to very quickly is lower metabolic costs. Those who train explosively, i.e., lifting the weight as quickly as possible, fatigue faster than if moving more slowly, even when using the same weight. This occurs because of the expedient utilization of ATP and faster accumulation of metabolic wastes. Utilizing limited muscle energy too quickly, while blocking channels of communication by hastily clogging up the system with waste, does not afford the chance for a muscle group to fatigue fully mechanically – or as much as it could. Overall, this means less tension time and less ATP uptake (relative to a longer tension time) to produce a much desired overcompensation effect. Muscle fibers are at the mercy of energy input and waste output, similar to a city requiring hydro electricity and necessitating garbage removal.

Reduced muscle tension and premature fatigue are minor concerns. Most important, fast or ballistic movement also increases the risk for injury. The area most susceptible to soft tissue injury is the myotendinous junction, where the muscle attaches to the tendon. If an athlete sustains a torn muscle or tendon, often the damage has occurred at that juncture. Considering that the purpose of exercise, particularly strength training, is intended to <u>enhance</u> functional ability; fast velocity and maximum acceleration must be eliminated from an exercise program to reduce the risk of injury.

Yet, moving too slowly, even if using the same weight, reduces the rate of neuromuscular firing, and allows the body to reduce effort (although moving progressively more slowly feels metabolically more demanding). This means less muscular force and less activation of Type IIb fibers – those responsible for the greatest growth. Do not misconstrue this statement, in that fast velocities = a higher rate of FT fiber activation. Rather, under the same load conditions, faster velocities result in greater forces, thus calling upon more fast-twitch fibers as a consequence. This information must be applied cautiously since moving too fast increases the risk of injury and can reduce overall muscle tension if the weight is thrown. And moving too slowly can reduce how much weight is lifted and, consequently, the degree of muscle tension.

There are various reasons why tension is reduced with very slow movement. First, as stated, the ability to lower a weight with greater ease allows for repose. Second, moving too slowly, in effect, links a series of intermittent isometric holds with dynamic movement. In other words, although very slow movement may be constant, the muscles quickly fluctuate or oscillate between isometric and dynamic states. And as in eccentric movement, the increased strength potential of the isometric phase allows for further repose.

Now, the measure of repose is magnified significantly if one considers that most exercises, even when quality machines with a varying resistance curve are used, have zones of harder and easier movement. A good example is the barbell squat. The bottom one-third, when the thighs are parallel with the floor or deeper is extremely demanding. Beyond that point, as the trainee stands upright, tension eases with little effort required to finish the top-third of the movement. It could be stated, then, that the top two-thirds of the exercise are not very challenging and the longer a trainee takes to complete the positive and negative phases, the more rest afforded and the more repetitions or the longer the TUT the trainee is capable of performing.[9]

The use of a metronome helps to maintain repetition consistency, thereby tracking of cadence and tension time, but the method can be misapplied. What sometimes happens is that trainees accelerate out of the most difficult zones of an exercise's ROM and slow down in the easier zones, all the while sustaining a particular cadence measure. So long as the cadence remains 4, 6, or 10 seconds, it may be viewed erroneously that every repetition is equal. Proper loading suggests the opposite, in that the trainee should move slightly slower during the more difficult segments, with some acceleration during the easier segments.

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[9] Experimentation clarified my understanding of how slow movement can affect lifting proficiency. By moving at a cadence of 10/10, I was able to perform nearly two minutes TUT with my bodyweight in the parallel bar dip exercise. At a cadence of 5/5, the TUT was approximately 70 seconds. At a cadence of 2/2, the TUT was about 40 seconds. The faster I moved, the faster I fatigued because of a high ATP uptake and accelerated metabolic waste buildup. The slower I moved, the more rest I allowed my muscles during the negative phase of the movement, as well as in the easier zones. The best effect (viz., physical conditioning and optimal muscle appearance) was achieved with a modest cadence of about 5/5 or slightly less. Strangely, the slowest speed felt more *systemically* demanding and fatiguing, although the overall results were not as good and slower movement required less muscular effort per repetition. This indicates either that the measure of overall fatigue one feels is not an indication of potential value or results, or that inroading that is too deep into the recovery reserves is not beneficial, as per the Principle of Diminishing Returns.

I.A.R.T. Research

Rapidity of Movement: Moving too rapidly in strength training will unload muscles and limit full range strength development adaptation

Abstract

Recommendations vary significantly in regard to how slowly or quickly a person should exercise when strength training, ranging from ballistic/explosive to the Superslow® protocol of 10 s concentric and 10 s eccentric. The purpose of our experiment was to determine the degree of forces produced and experienced by the tissues, by way of a digital force/strain gauge and computer plotting software, when moving under various conditions. It was concluded that there is little difference in the forces generated or experienced until trainees attempt to move a load explosively, to which forces increased by as much as 45 % initially, then decreased by 85.6 % for the majority of a repetition's tension time. With these findings it is apparent that trainees need to move slow enough to maintain tension throughout an exercise's range of motion and to avoid the higher forces experienced with explosive training and the consequential increase of tissue injury.

Introduction

A common recommendation in the strength training field is the promotion of explosive movement and ballistic/explosive movement, the former of which refers to accelerating a resistance as quickly as possible, whereby the latter (viz., the concept of 'ballistic') refers to implementing stored energy of the stretched tissues to rebound a load, followed by rapid acceleration. Regardless of the philosophical reasons for particular training methodologies, what is questionable are the results and safety with slow to moderate velocity, controlled strength training as opposed to explosive or ballistic/explosive strength training. Many studies have demonstrated that there is no difference in strength and power gains from slow as opposed to explosive training, yet there are studies that do contend that superior results can be achieved with slower training methods, likely because of the constant tension maintained on the muscles throughout an exercise's range of motion.

Mikesky et. al. (1) concluded that slower training produces better gains in hypertrophy, and Newton and McEvoy (2) found that slow resistance training improved baseball throwing velocity and bench press (6 RM) ability, whereas explosive medicine ball throws showed no improvement in baseball throwing velocity and inferior improvement in bench press ability. It is obvious that bench press ability would not improve much with medicine ball throwing, as per the Principle of Specificity, but the lack of results in throwing a baseball contradicts the popular philosophy that explosive exercise will enhance explosive sporting activities. Another study by Westcott, et. al. (3) demonstrated that slower movements (five 10 s concentric, one second pause, 4 s eccentric reps/set) in strength training likewise produced greater strength gains than with a shorter cadence (ten 2 s concentric, 1 s pause, and 4 s eccentric reps/set). The results were based on improved exercise performance, and not by other means of testing net muscular force.

It has been hypothesized that slower movements produce greater strength (and inevitable power) gains than moving quickly, likely because of greater and more consistent tension throughout the exercise's range of motion, and possibly rightly so. Nevertheless, to date this has not been explored sufficiently insofar as producing graphical representations of actual occurrences in muscle action. The quantification of muscle force development during contractions of different velocities can improve our understanding the implications of moving 'slow enough' as opposed to 'too fast' when prescribing an effective and safe exercise regimen. Consequently, the purpose of this study was to develop and record an experiment to determine the forces that transpire under different conditions of velocity, acceleration, and cadence protocols for a select muscle action (exercise) condition.

Methods

Subjects

With 25 years experience that has included several of the most common exercise methods, such as high-intensity, traditional high volume, bodybuilding, powerlifting and Olympic lifting, the author was used as the test subject. The use of a highly-experienced exercise enthusiast would guarantee better consistency and accuracy in exercise performance, consistent mechanics and testing quality than would a random subject with minimal or modest experience.

Procedures

The cable shoulder press was the exercise of choice, as depicted in the photo sequence below. The shoulder press is a common exercise to develop the shoulder and triceps for sport improvement that involves extension of the arm, such as shot putting and the throwing of a football or basketball, for example. The cable press version of this exercise allowed for the attachment of a strain gauge load cell (225 kg capacity) between the handle and the cable. The recorded force gauge data points, plotted using the WinWedge software (12-points per second collected; data searched and recorded every 50 ms) by way of the Dillon Quantrol AFTI digital force gauge (±0.1% accuracy with a peak capture rate of 2,000 Hz that is sensitive to 0.01 kg of force), began in the extended position (photo 1), brought to the bottom position (photo 2), and then lifted to the extended position (photo 3); from eccentric to concentric. The distance travelled was 61.5 cm, although closer to 66.7 cm with the ballistic/explosive protocol as the arm and shoulder pulled back to increase and implement the resultant stored energy.

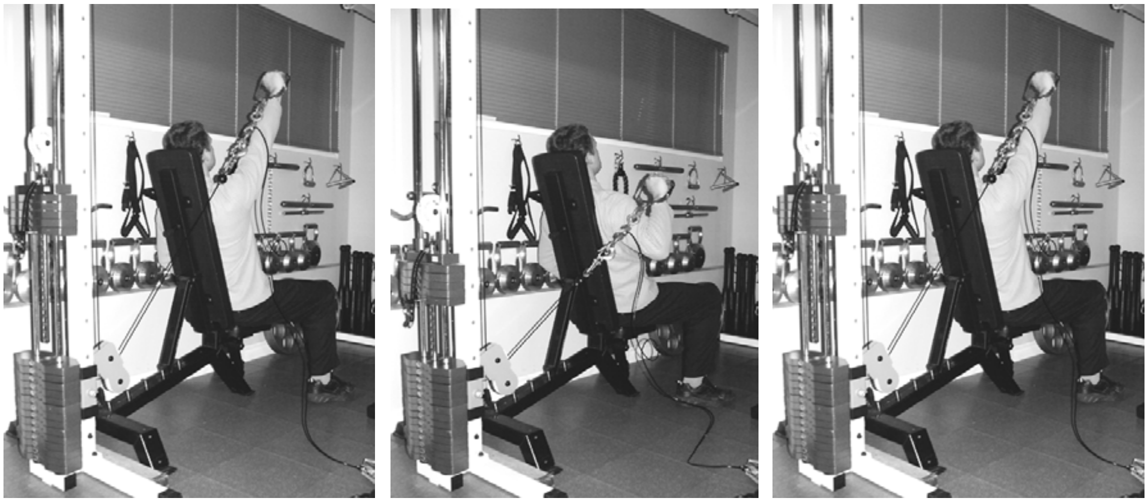

Figure 1. Photo sequence showing the action for the seated shoulder press.

The protocols tested with this exercise and presented in this paper, are as follows:

- Superslow® protocol of 10 s down and 10 s up.
- A reduced protocol of 5 s down and 5 s up.
- Nautilus protocol of 4 s down and 2 s up.
- Explosive protocol that involved accelerating the resistance up as quickly as possible to the top position, after a controlled 2 s eccentric phase.
- A ballistic protocol that involved lowering the resistance in approximately 2 seconds, rebounding from the stretched position, and then accelerating the resistance as quickly as possible to the top position.

15.4 kg of resistance was used (including the weight of the load cell/force gauge hardware and cable handle). It should be noted that explosive and ballistic training often employs lighter resistance than slower, controlled training, to allow for greater acceleration. However, to maintain consistency among the protocols, the same resistance was used, which was a light load for the test subject's ability and approximated 52 % of his 1 RM on that exercise. A heavier resistance was not used because of the increased risk of injury that is inherent with explosive and ballistic styles of exercise.

Also, two minutes of recovery were included between each protocol lift, to eliminate any fatigue, no matter how minimal, that could influence the subject's performance and/or mechanics among tests.

The subject was seated on a bench with a back support, with his legs and opposite arm relaxed to avoid body position changes. This allowed the recording of only the measure of forces and momentum that arose directly from the extended arm and shoulder or, at least, with as much control as was possible under the conditions. Certainly the measure of forces generated and experienced would be greater if the subject was allowed to employ extraneous muscle activity, as is common with explosive and ballistic styles of exercise.

Results

Figure 2 shows some initial disorder as the subject moved into place. He then lowered the resistance for 10 s, which depicts a wavering force between 12.61 kg and 13.43 kg (approx. data points 23-143). Less muscle force is required to lower the resistance of 15.4 kg because of minor machine friction and, otherwise, the weight would not lower, but remain static or rise. When the resistance was lifted, both the amount of muscle force and the resistance were nearly equal (a maximum of 15.74 kg at one point). Some disorder is shown after data point 232 as the subject lowered the cable handle to his side.

Also of note is the erratic line produced by the subject, a result of exercising against a resistance in an unstable environment (typical with cable exercises) and as the muscles work to find the center of balance within a plane of movement. Movement is never perfectly smooth, although a much smoother line (albeit still erratic to some extent) would be produced if exercising on a machine with a controlled path. In effect, and particularly when moving slowly, the muscles are in a constant state of flux, between acceleration and deceleration in an attempt to control velocity relative to time, and the faster one moves, the smoother a force curve would appear when measured and plotted.

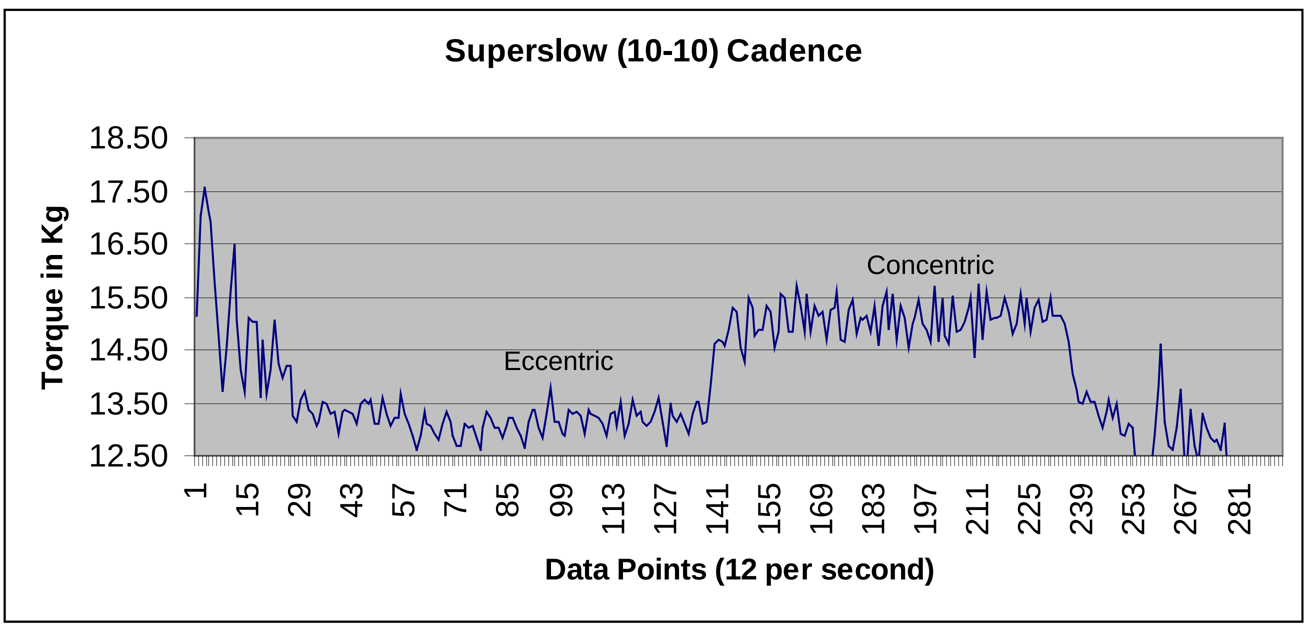

Figure 2. The continuous output from the strain gauge during an exercise sequence, using a 10-10 s protocol as described for Figure 1.

Tested next was a cadence at a value of half the rate of movement (5s - 5s), as shown in Figure 3. At a 5-5 cadence, the eccentric portion of the movement can be seen between data points 18 and 78 (once the subject 'settled in'), with forces that fluctuated between 12.11 kg and 13.88 kg. The concentric portion of the movement (approx. data points 78 to 130) averaged near 15.5 kg, but resulted in a maximum force of 16.06 kg; 0.32 kg greater than the highest force recorded with the 10-10 protocol. From this information, it was determined that there is very little difference in force produced/experienced by the muscles whether moving at a 10-10 or 5-5 cadence, and one protocol appears to provide as much tension on the muscles (and safety) as the other.

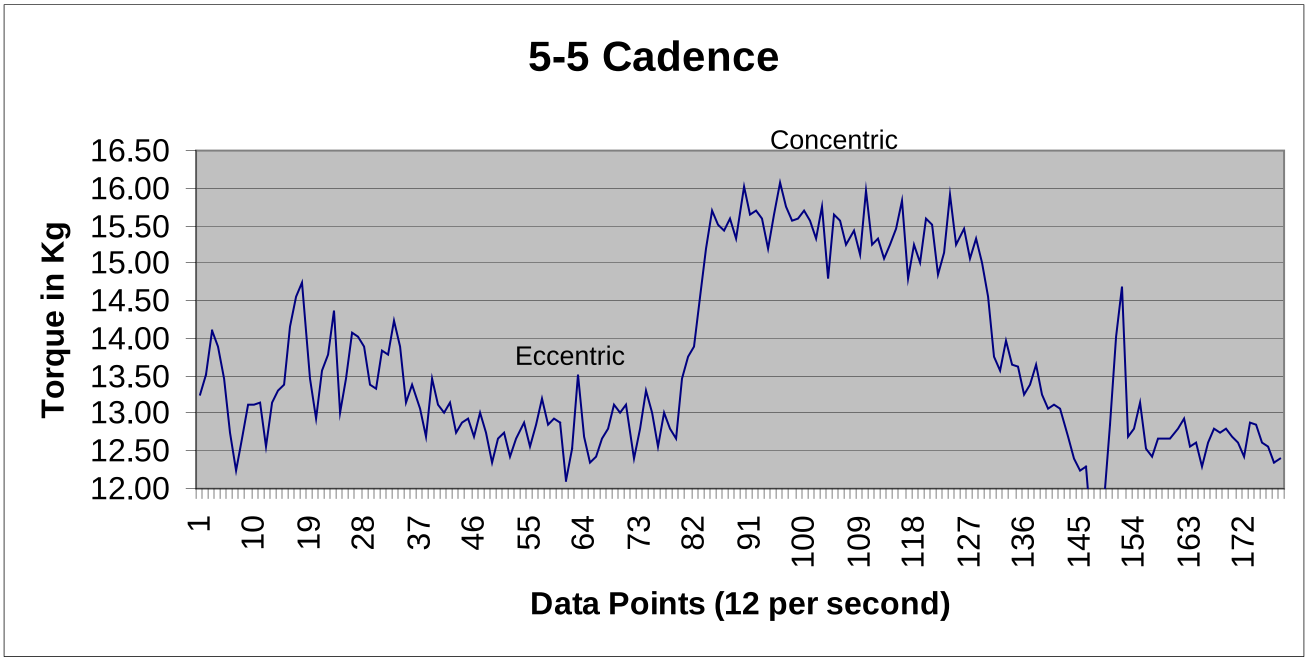

Figure 3. The continuous output from the strain gauge during an exercise sequence using a 5-5 s protocol, as described for Figure 1.

Another common cadence prescription is the Nautilus protocol of four s eccentric and two s concentric (4-2 protocol), as illustrated in Figure 4. Data points 30-72 represent the 4 s eccentric phase, and a force that fluctuated between 12.21 kg and 13.34 kg (less force overall than the eccentric of either the 10-10 or 5-5 protocol, which indicates less muscle activity is required to lower a weight quickly than to control its descent more slowly). The 2 s concentric phase (data points 72-96) had a peak force of 16.47 kg, or about 0.73 kg more than the weight used. This peak force also was only 0.41 kg greater than experienced with the 5-5 cadence, and 0.73 kg greater than experienced with the 10-10 protocol.

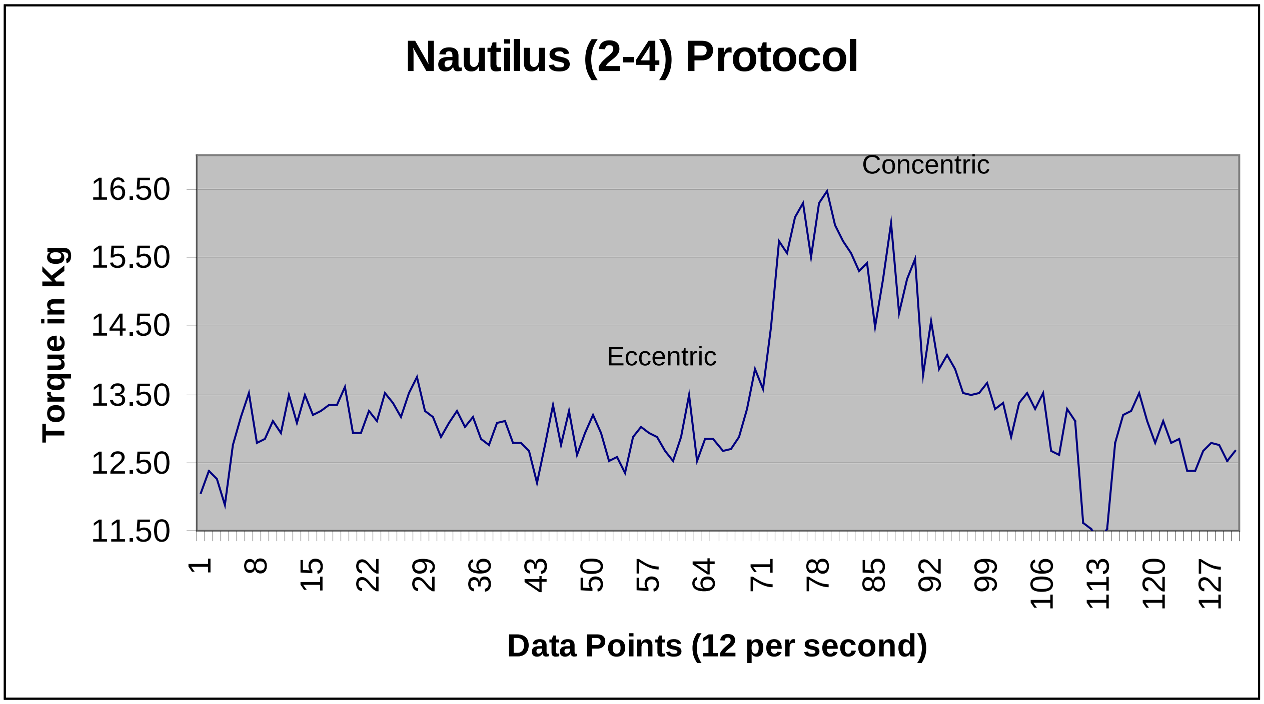

Figure 4. The continuous output from the strain gauge during an exercise sequence using a 2-4 s protocol, as described for Figure 1.

The next protocol involved explosive movement from a 'dead stop' position, at the bottom of the cable shoulder press and after an eccentric phase of 2 s. As revealed in Figure 5, there is less consistency with explosive training, since the amount of force produced on each repetition is affected by fatigue and motivation to accelerate a load as hard as possible. Two repetitions were recorded with that in mind, shown below, with a peak force of 24.64 kg exerted on the first repetition to move the 15.42 kg load at a maximal velocity.

The concentric portion of the movement lasted less than 1 s, and during that time, the working muscles experienced very little tension throughout the full range of possible movement, as shown by the dramatic force decrement to a low of 5.08 kg during the second repetition.

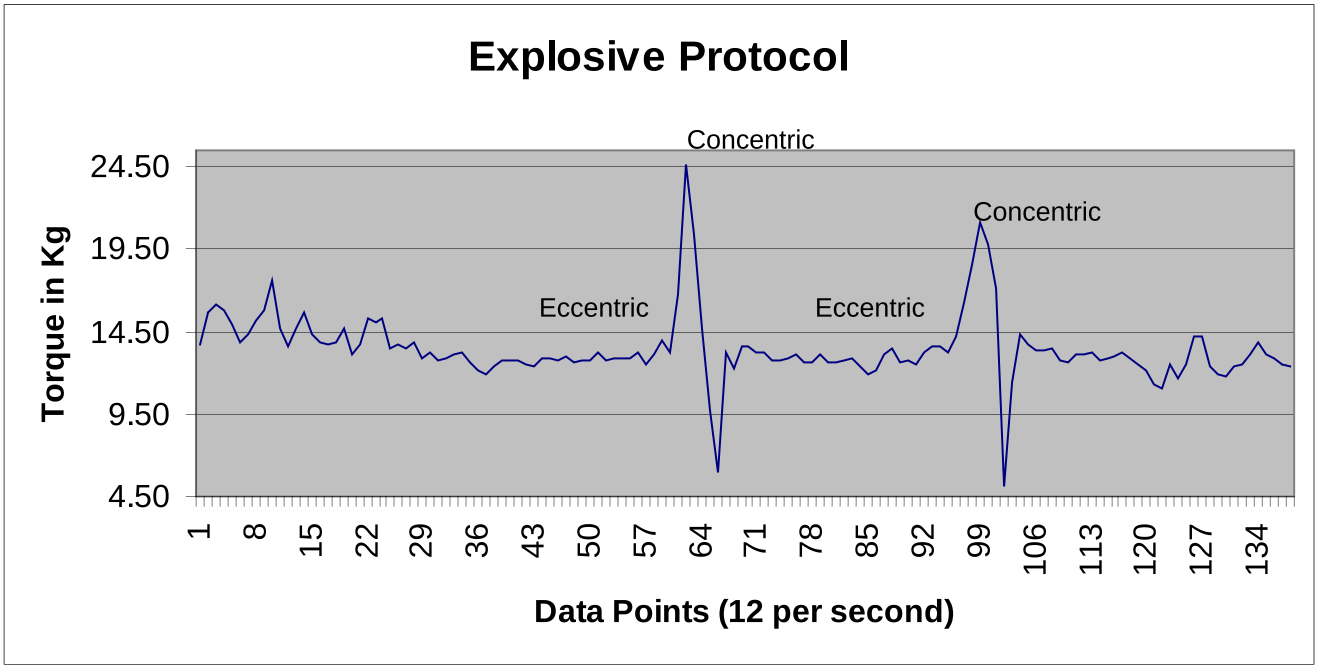

Figure 5. The continuous output from the strain gauge during an exercise sequence using an explosive protocol, as described for Figure 1.

Figure 6 presents that data from four repetitions performed with a rebound at the bottom position and then accelerated with maximum effort. The highest level of force occurred on the fourth repetition at 28.63 kg, and a low level of force on the first repetition at 2.2 kg. As with the previous graph, the low points are the result of the resistance being propelled upward (by use of stored energy [non-muscular torque] and momentum). Due to the momentum, muscular force development is reduced (nearly eliminated).

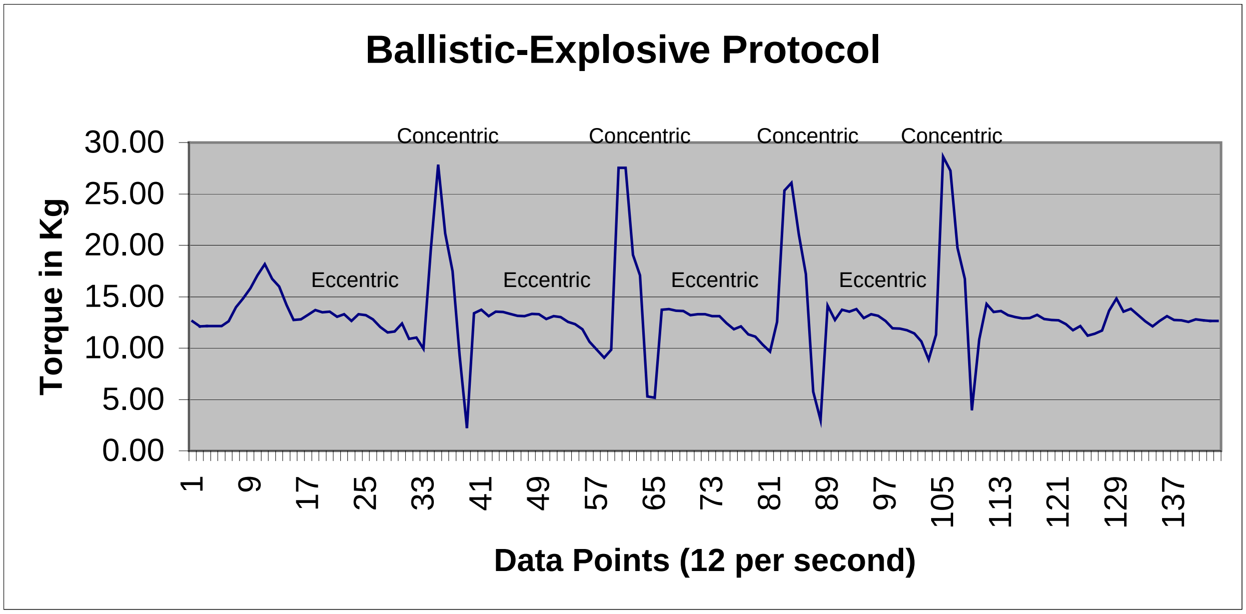

Figure 6. The continuous output from the strain gauge during an exercise sequence using an explosive-ballistic protocol, as described for Figure 1.

The following indicates the lowest, highest and mean forces during the concentric phase of each protocol. The explosive and ballistic-explosive protocols include the lowest and highest forces registered among the repetitions performed.

Protocol	Lowest Concentric Force	Highest Concentric Force	Mean Concentric Force
Superslow 10-10	14.29 kg	15.74 kg	15.02 kg
5-5	14.79 kg	16.06 kg	15.43 kg
Nautilus 4-2	15.74 kg	16.47	16.11 kg
Explosive	5.08 kg (2nd repetition)	24.64 kg (1st repetition)	14.86 kg
Ballistic-Explosive	2.22 kg (1st repetition)	28.63 kg (4th repetition)	15.43 kg

Discussion

From this data it can be seen that there is little difference, in regard to forces produced/experienced and the issue of safety (i.e., potential for injury as a result of unwanted and excessive forces) between the 10-10, 5-5 and 2-4 protocols. However, it should be noted that the above is true only if body mechanics and quality of form (including cadence timing) remain consistent from the beginning to end of a set and among all repetitions and among the protocols, which is not the case always, and particularly with complex free-weight movements, such as the squat. And sometimes it is not the measure of force changes that are a safety concern, but the distribution of forces along the tissues as mechanics alter. Consequently, it may be best to error on the side of safety and move 'slow enough' or slower than 'one thinks one should' to avoid unusual or high forces, and to be aware of proper form throughout a set of exercise. Certainly an experienced trainee could control these factors more effectively.

What also is apparent is that moving faster, and at some critical point, greater (noticeable and perceivable) forces must be produced to travel the same distance of ROM, i.e., to move a weight from point A to point B. In this instance, that critical limit is approximately 2 s, and relative to the exercise movement of a shoulder cable press. All of this should be obvious since greater acceleration, in order to cover the same distance in less time, will necessitate greater muscular force. Certainly more force is required to move at a cadence of 5-5 than 10-10, but the differences seem to be almost negligible, and perceivable only when reaching a particular threshold, as demonstrated with a 4-2 cadence, for example.

Once movement becomes rapid, as with explosive strength training techniques, forces increase significantly (upward of 33.1 % greater when compared to the highest force among the 2-4, 5-5 and 10-10 protocols), and it appears that the only area of the exercise's ROM that receives sufficient tension is at the beginning of the movement, just as the muscles exert a maximum force (and at the tissues' weakest and most vulnerable point for injury!). Thereafter, tension reduces to such an extent that a serious athlete or weight trainee would not even consider the load appropriate for a warm-up, let alone a work set. In this case, a low of only 5.08 kg of force was experienced for about 75 % of the movement's range.

Ballistic/explosive exercise appears to involve even less muscle tension throughout an exercise's full ROM, yet even greater forces upon initial movement at the bottom, stretched position (upward of 42.47% greater forces when compared to the highest force experienced among the 2-4, 5-5 and 10-10 protocols), partly as a result of stored energy and not muscular force. This means less muscular tension throughout the exercise's full range of movement (and strength developing results) and a higher risk of injury.

It has been suggested that athletes who utilize or require stored energy within their respected sports, such as a shot-putter, pole-vaulter, or javelin thrower, would benefit from ballistic-type exercise in the weight room. However, the specific mechanics, neurological patterns, and degree of activation among muscles during any strength training movement are non-specific to the sporting examples provided. In effect, enhancing one's ability through strength training is different than demonstrating that ability in *unlike* activities that require different mechanics, skills and application of one's strength, power and quickness, as per the Principle of Specificity. This conclusion has been supported repeatedly in the field of neurophysiology, as far back as 1949 (4), and which suggests that any degree of possible carryover from ballistic-type exercise to sports is no more relevant than slow, traditional strength training coupled with sport specific skill training (i.e., activity that incorporates *specific* ballistic adaptation and application). Consequently, the increased risk of injury that is inherent with higher force, ballistic and explosive strength training must be considered and given precedence when developing an exercise program for athletes worth millions of dollars.

Moreover, the requirement for full range strength training to obtain full range strength benefits has been accepted by some and questioned by others. What we have discovered at our testing and training facility is that the ability to improve in strength at all angles often results in the need to exercise all angles, although in some instances full range changes are possible with partial range exercise. Either of which depends on the individual and his or her muscle in question. However, even in those muscles that do produce full range results at all joint angles, with partial range exercise, the greatest changes do occur with direct exercise at a specific joint angle trained.

These findings have been supported by the research conducted by MedX Inc. and the Medical Department at the University of Florida (5) when each tested subject was considered individually. Similar results have been determined by Graves et al. (6), insofar as their subjects having produced the *best* results at a particular joint angle when exercising that particular joint angle, although full range benefits were produced to some extent even with partial range exercise. The Graves study likely would have concluded similar and varied results as we have and that of the University of Florida's research if each subject was considered rather than averaged within a group. As a research study colleague stated, "group data can always mask inter-individual differences." (7)

In effect, if explosive and ballistic/explosive exercise produces a high amount of tension at the onset of a movement, but with significantly decreased tension for the majority/remainder of the movement, it may be concluded that such training style does not produce full range strength results or, at best, inferior full range strength results when compared to moving "slow enough" to maintain a constant tension throughout the movement's exercised range. Certainly this needs to be considered, besides the fact of the increase of injury caused by rapid movement while strength training.

Conclusions

This experiment was undertaken to discover just how much momentum is involved in an exercise (the cable shoulder press) at different rates of movement and the duration of which momentum exists. This is an important factor since, in effect, if muscular change is partly the result of the muscular work stimulus, and if there is little work imposed on the muscles, then there would be little or no stimulus to produce positive change in muscular strength. Therefore, improvement in muscular strength, and particularly at specific joint angles (an important issue for athletes looking to enhance and fine-tune power output at particular body positions), requires deliberate and controlled strengthening exercises rather than ballistic/explosive activity, the latter of which emphasizes *reduced* muscular activity (net muscular force) by way of *increased* momentum and stored energy.

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7. Dr. Dave Smith, Chester College of Higher Education.

Proper Breathing

Proper breathing permits heavier lifting for more repetitions. It does this in two ways. First, regular and constant respiration help to remove metabolic wastes and provide energy to the muscles. Conversely, holding the breath or breathing too shallowly hastens lactic acid buildup and reduces nutrient flow to the muscles.

Second, by using the pressure and force of the diaphragm, it is possible to eke out an additional repetition or two before what typically would be perceived as muscular failure (this process is explained on the next page). This is why weight lifters hold their breaths while forcing out maximum attempts. The aim, however, is to limit the magnitude of breath holding without invoking the Valsalva Maneuver[1].

Over the course of months, proper breathing can contribute to a greater tolerance of exercise, overload of weight, and superior results. To get the most from the following instruction, however, exercise cadence must be slow enough to allow for a comfortable and steady pace in which to apply the technique.

The example below is based on a cadence of four seconds to lift and four seconds to lower, with a pause of one-second at the bottom and top positions. The slower the movement, the easier it is to control and coordinate breathing with movement. The timing, of course, ultimately depends on an exercise's range of motion since a forearm wrist curl would not take as long to complete as a chin-up, for example, and would not necessitate a cadence as slow as 4-1-4-1. A metronome is of benefit for obvious reasons, in that the trainee can coordinate the rhythm and movement of breathing patterns accordingly and accurately.

If only one aspect of proper breathing is remembered, it is this: As a weight lowers, begin taking in air about one-third from the bottom, stretch position, with all air taken in by the time you reach the bottom-most position. As the weight is 'squeezed' (lifted) up, begin exhaling.

[1] A condition wherein there is forcible exhalation against the glottis (a space between the vocal folds in the larynx) from holding one's breath and exerting, thereby increasing intrathoracic pressure, impeding venous return to the heart, and eventually fainting. Tabers Cyclopedic Medical Dictionary: 18th Edition. Thomas, Clayton L. M.D., M.P.H. F.A. Davis Company. PA: 1997. p. 2059.

Breathing Technique & the Squat Example

1. To begin, at the point of lockout, just before lowering the weight, take in a breath of air, filling the lungs about ¾ of the way. Then, for the first second down expire. This leaves three seconds remaining on the eccentric portion of the exercise.
2. During the 2nd second count, take in another breath of air, thus bringing the exercise to the halfway point in lowering the weight.
3. During the 3rd second count exhale, leaving one second remaining in the four-second negative, or lowering of the weight.
4. During the 4th second count, breathe in as much as possible (and what is comfortable) while descending to the bottom most position. Draw in air during the entire 4th second, and not as quickly as possible.
5. Hold the bottom position for a one-second count (to reduce stored energy torque/bouncing); it is at this point *only* that the breath should be held.[2]
6. After the one-second pause, forcefully exhale for two seconds, thus bringing the weight toward the halfway point on the lifting phase of the movement.
7. With two seconds remaining, immediately and quickly inhale, then exhale slowly for the duration of the repetition. Do not stop the weight while breathing; maintain fluid and steady movement.
8. Once at the top position, pause for a one-second count and inhale, thereby beginning the process for the next repetition.

As a trainee approaches muscular fatigue, breathing may become more erratic. The ability to sustain a particular breathing pattern ultimately depends on heart rate (heart rate often is governed by the demands of the exercise in question), and ability may change as a result. In essence, the more metabolically demanding the set, e.g., 1RM in the squat as opposed to 20-rep squats, and the more demanding the workout, e.g., the first set as opposed to the last set, the more labored and faster breathing becomes.

Nonetheless, it is essential to establish a controlled pattern, albeit a potentially evolving one that could have a trainee sounding like a chugging steam locomotive, breathing both in then out on every one-second count. The most critical aspect to remember is to continue breathing rhythmically and controllably, and to concentrate on the task at hand.

[2] Spinal stability and integrity increases when generating *intra-abdominal pressure*, a term that refers to the tautness of the abdominals, intercostals, and diaphragm that results when contracting the muscles of the midsection while holding one's breath. Pressure magnifies even more when wearing a support belt, thereby providing a surface for the abdominals to force against.

H. I. T.

Higher Intelligence Training

TOP SECRET

Chapter 4

Program Prescriptions and Physique Transformations

The first section of this chapter outlines basic directions for high-intensity program implementation. The purpose of such training is to produce quality body changes in minimum time, which application has been proven to be at least as effective as much higher volume and frequency programs, as found in fitness magazines and the general media. Do note that the exercise routine prescriptions and days in which to exercise are recommendations only and can be altered to accommodate the individual and equipment access. Consequently, it is the general direction that needs to be considered and not every specific contained herein.

A second section is provided on the general background of *Physique Transformations*, which information coincides with most 12-16 week 'quick fix' programs and their underlying directions, since doing so is very demanding on both mind and body. The majority of people who take the HIT challenge may be doing so to test the waters of an exercise program, to give such a program a try (after much frustration with other programs of higher volume and frequency), or to see physical changes. I am certain that some of the recommendations in that section will help direct an overall HIT program much better, and for those whose focus is on the extreme demands of physique transformation.

Developing a HIT Program

If a person is new to exercise, a program should begin with full-body implementation. Split training, whereby different body parts are trained on different days, can be implemented later on, if necessary and if preferred, but full body training should form the foundation initially. This serves many purposes. First, it makes learning of the exercises more concentrated and easier, since the individual does not have to think about what needs to be done on different body-part days, but is allowed to practice a handful of movements several times during the initial weeks. Second, a person has a better sense of a quality workout since the entire body feels worked. Third, easing into an intense program with less muscle soreness overall is more efficacious if the body-parts are trained several times over the initial weeks, and with *progressively* more intense effort.

An experienced trainee is encouraged to maintain a full-body workout, but may prefer a split routine, in order to concentrate on select muscles, although body-part specialization is possible with full-body training, as described later.

Beginner's Routine

Below is an example of a general full-body HIT routine… simple and to the point for quick learning and maximum effort of few exercises.

Weeks 1-2

Direction: Full Body Routine x 3 Sessions Per Week

Focus: Exercise technique, proper breathing, and learning to exercise hard

Tension Time: 60-90 seconds per set @ 5-5 cadence (=6-9 repetitions per set)

Rest Between Sets: 2 minutes

Total Workout Time: 25-29.5 minutes excluding warm-up

Days 1-3 (Mon-Wed-Fri)
1. Leg Press (quadriceps, hips/gluteals, hamstrings, and calves) 2. Leg Curl* (hamstrings) 3. Pulldown (upper back, biceps, shoulders, and forearms) 4. Chest Press (pectorals, shoulders, and triceps) 5. Overhead Press (shoulders and triceps) 6. Biceps Curl (biceps and forearms) 7. Triceps Extension** (triceps) 8. Abdominal Crunch (abdominals and obliques)

With each workout, emphasize intensity of effort in 3 of the 9 exercises; select a second set of 3 exercises in the second session, and a third set of 3 exercises in the third session.

* Alternate the leg curl and leg press every other workout, so that the leg curl and hamstrings are worked and emphasized first.

** Although the triceps are a larger mass than the biceps, they are trained after the biceps (to allow for a modest rest) because of the stimulus (elbow extension) received in the chest and shoulder exercises.

In the next two weeks, the trainee should be training to fatigue, or pretty close to fatigue on all exercises, and with 30-seconds less rest between exercises to increase overall demands.

Weeks 3 & 4

Direction: Full Body Routine x 2 Sessions Per Week

Focus: Exercise that approaches muscular fatigue

Tension Time: 60-90 seconds per set @ 5-5 cadence (=6-9 repetitions per set)

Rest Between Sets: 90 seconds (a 30-second reduction in rest between sets to increase exercise demands)

Total Workout Time: 21-25.5 minutes excluding warm-up

Day 1 (Mon)	Day 2 (Fri)
1. Leg Press 2. Leg Curl 3. Pulldown 4. Chest Press 5. Overhead Press 6. Biceps Curl 7. Triceps Extension 8. Abdominal Crunch	1. Leg Curl 2. Leg Press 3. Pulldown 4. Chest Press 5. Overhead Press 6. Biceps Curl 7. Triceps Extension 8. Abdominal Crunch

Certainly a trainee can continue to maintain the above program, to keep it simple, but some people may desire greater exercise demands, to challenge the body better. This can be done in several ways. One way is to implement a set variable known as ***pre-exhaustion***, whereby a single-joint exercise is followed by a multi-joint exercise. This technique doubles up on set volume for a select muscle and is described further on page 94.

Another way is to implement other set variables that alter the manner in which a set is performed. Some variables are less strenuous, such as performing 1¼ reps, whereas others increase exercise demands dramatically, such as forced and negative repetitions (see Chapter 5 for explanations of set variables). Less strenuous variables should be introduced first so as not to overwhelm the trainee too much, too soon.

Even more demanding would be the inclusion of both pre-exhaustion and other set variables. First, however, let's look at the program initially developed, with only 8 exercises, and what a program could look like with the inclusion of different set variables. But do keep in mind that this is very tough training, to optimize results in limited time, and not all trainees will be able to tolerate exercise this hard and concentrated. Moreover, set rests are reduced to only 60-seconds, from 90-seconds, thus making exercise more challenging still.

Weeks 5 -8

Direction: Full Body Routine x 2 Sessions Per Week

Focus: Exercise that approaches muscular fatigue in one workout (with set variables), and sub-fatigue in the next workout (without set variables); a sub-fatigue workout is included *only if* intensity of effort is high on Day 1; repeat Day 1 if intensity of effort is insufficient

Tension Time: 60-90 seconds per set @ 5-5 cadence unless incorporating particular set variables

Rest Between Sets: 60 seconds (a 30-second reduction in rest between sets to increase exercise demands)

Total Workout Time: Approximately 17-21.5 minutes excluding warm-up

Set Variables: Inclusion of 1¼ reps, Stutter Reps, 21-Method, Bottom Partials, One-repetition method, Isometrics, and Static (+ negative)

Weeks 5 & 7	
Day 1	**Day 2**
To-fatigue w/ Set Variables	**Sub-fatigue no Set Variables**
1. Leg Press (one-rep method)	1. Leg Curl
2. Leg Curl (1¼ reps)	2. Leg Press
3. Pulldown (stutter reps)	3. Pulldown
4. Chest Press (bottom partials)	4. Chest Press
5. Overhead Press (21-method)	5. Overhead Press
6. Biceps Curl (assist isometric at half-way point)	6. Biceps Curl
7. Triceps Extension (self-contained isometrics at half-way point)	7. Triceps Extension
8. Abdominal Crunch (1¼ reps)	8. Abdominal Crunch

Weeks 6 & 8	
Day 1	**Day 2**
To-fatigue w/ Set Variables	**Sub-fatigue no Set Variables**
1. Leg Curl (stutter reps)	1. Leg Press
2. Leg Press (bottom partials)	2. Leg Curl
3. Pulldown (21-method)	3. Pulldown
4. Chest Press (1¼ reps)	4. Chest Press
5. Overhead Press (self-contained isometrics at half-way point)	5. Overhead Press
6. Biceps Curl (top partials)	6. Biceps Curl
7. Triceps Extension (1¼ reps)	7. Triceps Extension
8. Abdominal Crunch (21-method)	8. Abdominal Crunch

In Week 12 there will be a sub-focus of to-fatigue workouts without set variables; these are standardized workouts as performed in the initial weeks, used to determine and compare improvement from the initial weeks.

Weeks 9 -12
Direction: Full Body Routine x 2 Sessions Per Week
Focus: Exercise that approaches muscular fatigue in one workout (with set variables), and sub-fatigue in the next workout (without set variables); a sub-fatigue workout is included *only if* intensity of effort is high on Day 1; repeat Day 1 if intensity of effort is insufficient
Tension Time: 60-90 seconds per set @ 5-5 cadence on average, unless incorporating particular set variables
Rest Between Sets: 60 seconds
Total Workout Time: Approximately 17-21.5 minutes excluding warm-up
Set Variables: Inclusion of Negatives, Overloads, Descending Sets and Forced Reps

Weeks 9 & 11	
Day 1	**Day 3**
To-fatigue w/ Set Variables	**Sub-fatigue no Set Variables**
1. Leg Press (alt-neg)	1. Leg Press
2. Leg Curl (descending set)	2. Leg Curl
3. Pulldown (forced reps x 2-3)	3. Pulldown
4. Chest Press (forced overloads)	4. Chest Press
5. Overhead Press (alt-neg)	5. Overhead Press
6. Biceps Curl (forced neg)	6. Biceps Curl
7. Triceps Extension (forced neg)	7. Triceps Extension
8. Abdominal Crunch (pure neg)	8. Abdominal Crunch

Week 10	
Day 1	**Day 2**
To-fatigue w/ Set Variables	**Sub-fatigue no Set Variables**
1. Leg Curl (alt-neg)	1. Leg Press
2. Leg Press (descending set)	2. Leg Curl
3. Pulldown (alt-neg)	3. Pulldown
4. Chest Press (alt-neg)	4. Chest Press
5. Overhead Press (descending set)	5. Overhead Press
6. Biceps Curl (max overloads)	6. Biceps Curl
7. Triceps Extension (+ 3 neg)	7. Triceps Extension
8. Abdominal Crunch (descending set)	8. Abdominal Crunch

Week 12	
Day 1	**Day 3**
To-fatigue no Set Variables	**To-fatigue no Set Variables**
1. Leg Press	1. Leg Press
2. Leg Curl	2. Leg Curl
3. Pulldown	3. Pulldown
4. Chest Press	4. Chest Press
5. Overhead Press	5. Overhead Press
6. Biceps Curl	6. Biceps Curl
7. Triceps Extension	7. Triceps Extension
8. Abdominal Crunch	8. Abdominal Crunch

Pre-exhaustion*

The purpose behind pre-exhaustion is to increase muscular inroad, with the help of other muscles and within a very concentrated time. This makes exercise application more effective, but without including an excess number of sets/time investment, and to limit the negative effects on recovery ability. Arthur Jones popularized this method of exercise and used it extensively in his work with athletes and professional bodybuilders.

An example of a pre-exhaust would be the performance of a pec deck or some other type of flye to fatigue the pectorals, quickly followed by a chest press or dip to further fatigue the pectorals with support by the 'fresh' triceps and deltoids. In other words, a single joint (SJ) movement followed by a multi-joint (MJ) movement. A reverse pre-exhaust would be the performance of a MJ movement first and then the SJ movement, and doing so can be alternated every other workout with regular pre-exhaust.

Below is an example of a full-body pre-exhaust workout for all the major muscles of the body. Bear in mind that the total volume of sets is somewhat high, and that the pre-exhaust method would need to be split in two, so that half the body is pre-exhausted one workout (while the other half performs only one set to fatigue), and the remainder would pre-exhaust in a subsequent workout. More extensive "double pre-exhaustion" can occur, such as leg extensions + leg press + squat, i.e., two MJ movements that follow one SJ movement, or a MJ movement + SJ movement + MJ movement. However, including these many sets should be reserved for body part specialization programming, as described later in this chapter.

Target Muscle	SJ Exercise	MJ Exercise	Assistant Muscles in the MJ Exercise
Quadriceps	Leg Extension	Leg Press/Squat	Hips, gluteals, hamstrings
Hamstrings	Leg Curl	Stiff-Leg Deadlift	Hips, gluteals, lumbar
Upper Back	Pullover	Pulldown/Chin	Biceps, brachialis, deltoids
Pectorals	Pec Deck	Chest Press/Dip	Deltoids, triceps
Shoulders	Lateral Raise	Overhead Press	Triceps
Biceps	Curl	Undergrip Pulldown/Chin	Upper back, deltoids
Triceps	Extension	Close Grip Press/Dip	Pectorals, deltoids
Abdominals	Crunch	Sit-up	Hip Flexors
Calves	Calf Raise	Skipping or cardio sprinting	Thighs + stored energy
Inner Forearms	Wrist Curl	Static Grip Hold	Finger grip
Outer Forearms	Reverse Wrist Curl	Reverse Curl	Brachialis & biceps

* If included, apply this variable after the initial 5-6 weeks of a beginner's routine, and once proper form and understanding of intense exercise occurs.

General Comments and Direction

- It may be necessary to deviate from the calendar week when developing a program, for reasons of convenience, preference, or recovery ability. For example, rather than exercising on Monday and Friday, training could take place on Monday, Saturday, Wednesday, etc. In such an instance, the example 12-week program provided earlier would alter accordingly. Nonetheless, each muscle should be trained at least once every 7-9 days to reduce muscle soreness between sessions.
- If a trainee prefers or is able to exercise non-stop between exercises in a full-body program, it should be encouraged, and including aerobic, steady-state day would be unnecessary (to stimulate an improvement in cardiovascular/respiratory ability). Keep track of heart rate during strength training sessions to make certain it remains within the 'target' zone.
- To sustain motivation and a more favorable stimulus for the muscles, once graduating from the 12-week sample program, select 4-6 exercises per muscle and rotate 2-3 each workout for variety and greater challenge, such as lying leg curls, leg extensions and horizontal leg press one workout, followed by a 45° leg press, hack squat, and standing leg curl the next. Set variables then can alter among these exercises and in different sequences.
- During the sample 12-week program, it is necessary to work the body from the largest to the smallest muscles. The largest are worked first, when energy is highest and since those large muscles afford the greatest 'indirect' anabolic and metabolic effect throughout the body (e.g., working the leg press or squat exercise very hard will affect the muscles of the upper body to some degree). The smallest muscles are worked last, since they are the 'weak links' in many exercises that affect the large muscles and are easier to work even as energy begins to wane.
- Do not exceed 90 seconds tension time, since doing so increases the development of muscular endurance and has less of an effect on optimizing strength and muscle mass (particularly as the energy systems shift from anaerobic to aerobic). However, sets should last at least 40-60 seconds, to provide sufficient tension time with a moderate weight and a reduced risk of injury. *In general*, tension time of 50-70 seconds is appropriate for the upper body muscles, and upward of 90 seconds is appropriate for lower body muscles.
- A warm-up often is necessary, and could include 5-6 rhythmic repetitions on each station for the legs and torso, and at 50-60% the intended work weight (the arms, shoulders, midsection and low back will receive an indirect effect and do not necessitate a warm-up unless preferred). It may be discovered that the lower body requires more of a warm-up than the upper body, with the inclusion of 1-2 additional light sets or a few minutes on an exercise bike or some other steady-state device. A cool-down likely is unnecessary since the small muscles are worked last and heart rate should not be too high at that juncture. If heart rate is still approximately 60% of maximum, then include a cool-down on a steady-state device (or jog slowly on the spot) at a slow to moderate speed (low tension) for 3-5 minutes.
- When possible, improve through the double-progression method, i.e., an increase in both the load and the repetitions/TUT.

- Certain direct training should be avoided in women, such as calf and trapezius exercises, to avoid development of muscles that could distract from overall aesthetics.
- A 1-2 week layoff after the initial 12-week sample program will do a trainee good, for both recovery and anxiousness to get started into the next level. One to two week layoffs should be implemented every six months, or when deemed appropriate (although most trainees feel guilty in doing so and will avoid layoffs in the mistaken belief that muscles will shrink and weaken).

Split Routines

It is unnecessary to split a routine, from a full-body program, but some people prefer concentrating on a few muscles at a time (and may find full-body exercise a bit daunting). Doing so also allows a person to increase total set volume per muscle to enhance body part specialization, to be discussed next. However, doing so also increases the risk of a person slowly increasing set volume too much, since doing so is easier on a split routine than it is on a full-body routine.

A split routine could include a two-way or three-way split of the body. Developing more splits would mean more workout days and less recovery time and, therefore, are not recommended. Combining the appropriate body parts for each split is essential, to avoid too much 'cross-over' of stimulus. A two-way split, for example, could consist of upper body one day and lower body another day. On the lower body day, some smaller muscles could be included, as per this suggested layout:

Workout 1 (Upper Body)	Workout 2 (Lower Body + Small Groups)
Back, Chest, Shoulders, & Upper Arms	Thighs, Calves, Abs, Rotator Cuffs, Neck, & Forearms

If the upper body routine appears too challenging, particularly if 3-4 sets per muscle are preferred or deemed appropriate, then Lower Body + Upper Arms can be combined, but under two conditions:

1. There is sufficient recovery time before the Upper Body (torso) workout, since fatigued arms will hamper torso exercises.

2. Upper body workouts include single-joint movements, such as machine pullover, pec deck and lateral raise, so that less work is afforded the arms and more so on the torso muscles.

A three-way split should group muscles that work together. For instance, when performing a pulldown exercise for the upper back, the biceps, forearms, and shoulders (posterior deltoids) also work. Consequently, they should be grouped together. The same is true of the shoulder (anterior deltoids) and triceps when training the pectoral muscles with pressing and dip exercises. Consequently, the following three-way split is the most logical:

Workout 1	Workout 2	Workout 3
Back, posterior deltoids, biceps, and forearms	Quadriceps, hamstrings, hips/gluteals, and calves	Pectorals, anterior and lateral deltoids, and triceps

- Posterior deltoids are involved in rowing and chinning movements, and should be included on back day.
- The anterior deltoids are stressed greatly during most pectoral exercises, and should be included on that day.
- Abdominals could be included in any workout.
- Direct low back work should be included with legs if squats are part of the program, since fatiguing the low back a few days prior to squats could increase spinal flexion due to weakening of the lumbar muscles, and fatiguing the low back a few days after squats could result in excess frequency of activity for the lumbar muscles. Both factors can increase the risk of injury.
- Rotator cuff training could be on pectoral/shoulder day, but not necessarily.

Body Part Specialization

If a split routine is incorporated it is a good idea to alternate one's focus, such as training the back, chest and shoulders very hard one week (or however often each muscle is trained), and then training the remaining muscles hard the following week/workout. 'Hard' training could involve to-fatigue exercise, the inclusion of set variables, the number of sets (e.g., 3 vs 1-2), or priority within a workout (e.g., trained first).

The idea of 'altering' workout demands fits well with the concept of body part specialization. This direction in exercise means an increase in overall demands, as well as prioritizing a select muscle group(s) within a workout. People choose to specialize for one of two reasons: 1) because they like training a particular muscle, or 2) because a particular muscle is lagging in development and some 'shock' training may help to bring it up to par. The first reason should be avoided when possible, since over-development of a muscle can result in injury because of tissue/strength imbalance around a joint, besides an odd appearance to the body as a whole. And readers need to be made aware that 'spot-reduction' is impossible, and so doing extra work for the hips, abdominals or some other 'fatty' area will not accelerate change (fat loss) in an area.

The following two pages provide examples of body part specializations within a full-body workout, with the following points to be kept in mind.

- These specialization routines also can be implemented in a split routine, if desired.
- Include no more than 30-seconds rest between specialization sets to increase overall exercise demands.
- Perform no more than two circuits of the specialization sequence and with a few minutes rest between circuits; often one circuit will be sufficient if intensity of effort is maximal, and particularly with advanced trainees.
- Perform only one set each for the remaining body parts to keep total set volume within reason.
- Specialization should not occur for more than two workouts per week for any one muscle, and for no more than two consecutive weeks. Thereafter, two weeks of 'typical' training should be performed before including another two-week period of body part specialization, and preferably for a different muscle or area.
- Two-week blitzes for any one muscle should occur no more than once every two months, to allow for recovery and sufficient 'shock value' when re-introduced. Attempting too much or blitzing too often for any muscle can result either in localized over-raining or over-adaptation to the stimulus.
- It is a good idea to select different equipment whenever specializing, to create a unique environment for the muscles.
- The *Set Variables* presented in Chapter 5 can be incorporated and as the instructor deems appropriate; doing so will increase exercise demands accordingly and produce a better overall response (so long as the set volume and frequency are appropriate).

Thigh Specialization	Back Specialization
Leg Curl Leg Extension Leg Press Squat Pulldown or Row (back) Chest Press or Dip (pectorals) Lateral Raise (shoulders) Biceps Curl (biceps) Triceps Extension (triceps) Abdominal Crunch (abs) Low Back Extension (spinal erectors)	Pullover Pulldown or Chin-up Row Shrug Low Back Extension Leg Press (thighs) Chest Press or Dip (pectorals) Lateral Raise (shoulders) Biceps Curl (biceps) Triceps Extension (triceps) Abdominal Crunch (abs)
Chest Specialization	**Shoulder Specialization**
Pec Deck Chest Press (incline, decline or flat) Cable Crossover Dip Leg Press (thighs) Pulldown or Row (back) Lateral Raise (shoulders) Biceps Curl (biceps) Triceps Extension (triceps) Abdominal Crunch (abs) Low Back Extension (spinal erectors)	Lateral Raise Bent Raise Shoulder Press Armpit Drag Leg Press (thighs) Pulldown or Row (back) Chest Press or Dip (pectorals) Biceps Curl (biceps) Triceps Extension (triceps) Abdominal Crunch (abs) Low Back Extension (spinal erectors)
Biceps Specialization	**Triceps Specialization**
Drag Curl Biceps Curl Pulldown or Chin-up (top half) Leg Press (thighs) Pullover, Shrug or Row (back) Chest Press or Dip (pectorals) Lateral Raise (shoulders) Triceps Extension (triceps) Abdominal Crunch (abs) Low Back Extension (spinal erectors)	Reverse Grip Bench Press Triceps Extension Dips (or negative-only dips) Leg Press (thighs) Pulldown or Row (back) Pec Deck (pectorals) Lateral Raise (shoulders) Biceps Curl (biceps) Abdominal Crunch (abs) Low Back Extension (spinal erectors)

Forearm Specialization

Reverse Wrist Curl
Reverse Curl
Wrist Curl
Static Grip Hold
Leg Press (thighs)
Pulldown or Row (back)
Chest Press or Dip (pectorals)
Lateral Raise (shoulders)
Biceps Curl (biceps)
Triceps Extension (triceps)
Abdominal Crunch (abs)
Low Back Extension (spinal erectors)

Calf Specialization

Seated Calf Raise
Standing Calf Raise
Skipping for 2 minutes or sprinting on
Stairclimber (on toes) for 60 seconds
Tibialis Extension (DARD)
Leg Press (thighs)
Pulldown or Row (back)
Chest Press or Dip (pectorals)
Lateral Raise (shoulders)
Biceps Curl (biceps)
Triceps Extension (triceps)
Abdominal Crunch (abs)
Low Back Extension (spinal erectors)

Abdominal Specialization

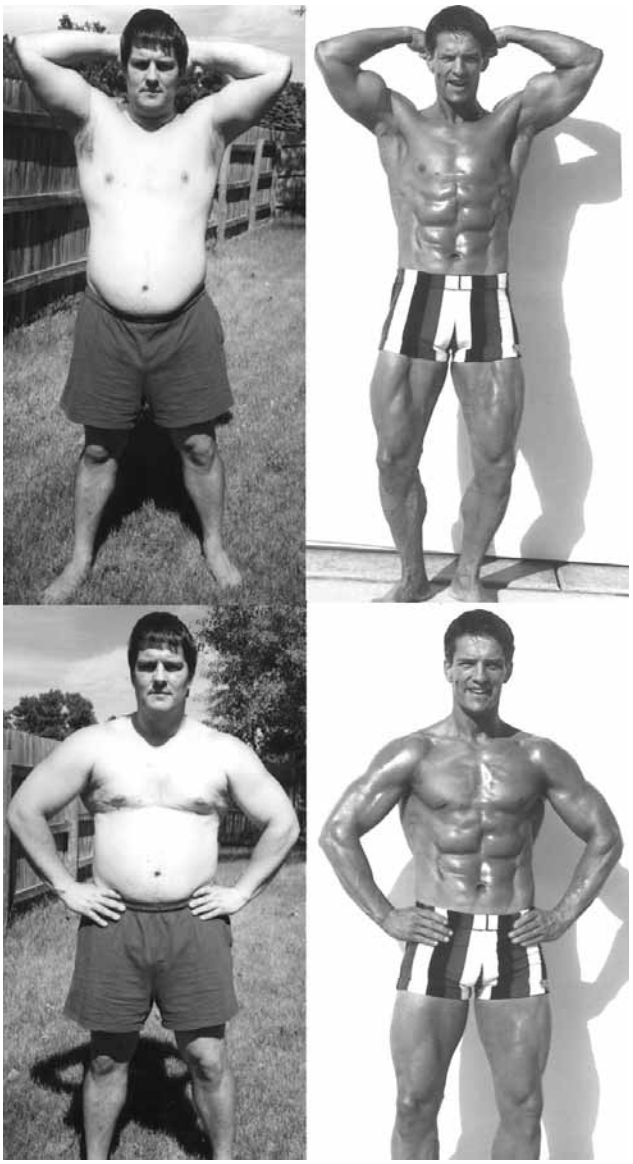
Ab Crunch
Side Cable Crunch
Sit-up and/or Handing Leg Raise
Rotary Torso
Leg Press (thighs)
Pulldown or Row (back)
Chest Press or Dip (pectorals)
Lateral Raise (shoulders)
Biceps Curl (biceps)
Triceps Extension (triceps)
Low Back Extension (spinal erectors)

Neck Specialization

Neck Flexion
Neck Extension
Lateral Extension (right and left)
Rotary Neck
Shrug
Leg Press (thighs)
Pulldown or Row (back)
Chest Press or Dip (pectorals)
Lateral Raise (shoulders)
Biceps Curl (biceps)
Triceps Extension (triceps)
Abdominal Crunch (abs)
Low Back Extension (spinal erectors)

Physique Transformation[*]

By now you have all seen them. The before picture: sloppy, out of shape people looking miserable while posing in a swimming suit. The after picture: tanned, trim and smiling look-alikes (minus the fat).



Brian Erickson's incredible 12-week transformation!

In shocked disbelief or cynical skepticism, you analyze and scrutinize the pictures with great interest. Are these people really your genetically average 'Everyday Joes?' Are they a bunch of people who previously had wonderful physiques, got out of shape, and then made a comeback? In a nutshell, are these contests truly a legitimate mechanism to help thousands of people acquire their dream body, or are they just commercialized opportunities for supplement companies to profit by infecting the masses with a 'fitness epidemic?' ARE THESE CONTESTS ALL THAT THEY'RE CRACKED UP TO BE? They can be. But having a proper (healthy) perspective on the transformation contest mindset before competing is most important. To be truly successful, transformation contests need to be part of, not apart from, a realistic, lifelong fitness program.

A few months before my 40th birthday, I was a stereotypical middle-aged overweight male. I had literally lost any semblance of a neck, and at five foot eleven inches tall, I was at the point of graduating to a pant size with a 40-inch waist. The only difference that separated me from other 'Beefy Boys,' was that I had spent most of my adult life researching, then trying most of the weight training/fat loss programs out there. Faithfully, I would work out, focusing mostly on lifting weights, my motto being: "I may be fat, but I'm strong."

[*] This section written by Brian Erickson, for *Exercise Protocol* magazine, Spring 2001, and featured in the book *I.A.R.T. Journals 1995-2001*.

But, regardless of how I tried to rationalize it, I knew I was overweight and I felt rotten. I was constantly tired, often irritable, and spent my days trying to conserve energy, just to be able to complete my workouts. Something wasn't clicking. I couldn't figure out how to get into the shape I wanted.

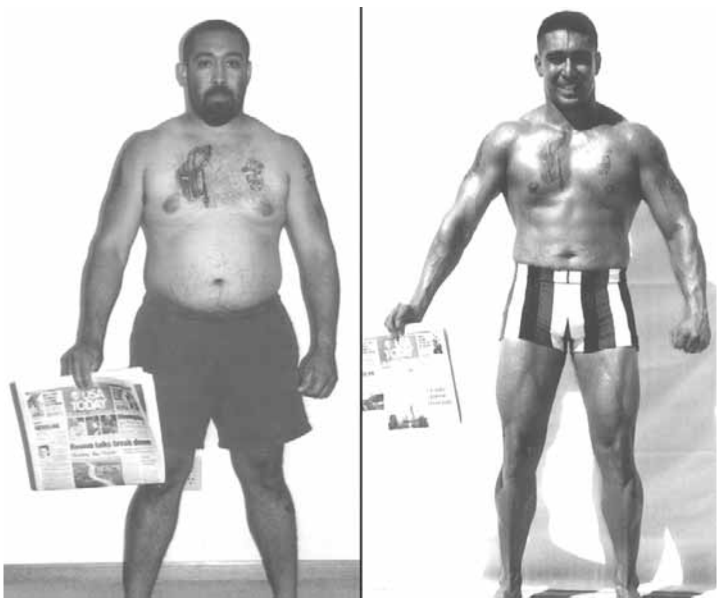
It was in the summer of 1998 that I decided to compete in the EAS Physique Transformation Challenge. For 15 weeks I used every piece of information on nutrition, training, and supplementation that I had ever got my hands on. The difference now was a 'carrot at the end of the stick', which seemed to motivate me as never before. During the contest, I lost 47 pounds of scale weight while taking my body fat from 25% to 8%. My transformation placed me second runner-up in my age category (see photo collection 1), earning me a notable amount of magazine exposure and other prizes from EAS. As a result of that experience, I pursued my dream of becoming a certified personal trainer. I began training others and sharing with them the means to acquire such drastic results.

This led me to my second contest in the spring of 2000. I competed, and placed, in the Met-Rx World's Best Personal Trainer Contest (see client in photo set 2, Mace Costillo). This contest involved training a client for 12 weeks and submitting pictures, training journals, workouts and nutrition plans. My winnings included a spot on a Met-Rx/GNC television commercial, all expense paid trips to California (on two occasions) and prizes including workout gear, supplements, clothing, weights, etc. It was at this time that I became familiar with the I.A.R.T. (www.ExerciseCertification.com) and met Brian Johnston (one of the judges) for the first time.

Looking back, this was pretty heady stuff for a 'small town boy,' and I am grateful for these opportunities. After all, these contests inspired me to make a career change and reset my standard for my own physical health, which continues to improve day by day. But now that I have trained numerous other individuals for contests, I realize that my own post-contest mindset seems to be an exception to the rule. With this observation, I needed to take a look at the bigger picture of transformation contests. The realm of physique transformations can be a double-edged sword, and I believe it is necessary, especially as a trainer working with others involved in contests, to take a closer look at this.

Anyone considering entering a physique transformation contest needs to understand that the contests' key purpose is, in my opinion, to market products/supplements. The sponsor wants to make money, plain and simple. What better way to do that than to take a group of discouraged, frustrated people and entice them with money, trips, and media exposure if they have success with its product. Don't get me wrong, supplements can be helpful, and I am all for using any healthy approach to allow people to quickly reach their goals. But without good training, good eating, adequate rest/recovery, and strong determination, all the supplements in the world aren't going to make your 'before' and 'after' pictures worth sending in. In spite of all the marketing genius involved in the design of the successful contests out there today, you've got to keep focused on the most important reasons people make great (natural) gains – commitment to good eating and hard training.

Another important area is the struggle to stay focused on an overall training program that is reasonable and healthy. Many people find that contests make it hard to stay focused on life-long, healthy training principles, due to the desire to 'totally transform' in only 12 short weeks. THE CONTEST suddenly becomes an idol, while learning and practicing good fitness habits take second place and become only a means to a very short end. I believe that transformation contests should only be stepping-stones. They should be opportunities to learn and practice good training and eating habits that should be built upon for the rest of your life. Drastic changes in eating habits, reoccurring or new injuries, obsessions, compromises in time, and relationship commitments can all end up being worthless sacrifices if people see them merely as means to the ultimate (contest) end. <u>Don't make that mistake.</u>



Mason Costillo (Brian Erickson's Pupil)

The Contest Mindset

Physique transformation contest sponsors use (effective) marketing strategies to 'set the hook' so that anyone believes that he/she can, and will, win. This is a very effective and generally true approach if you really look at the odds.

In the 1998 contest I participated in, there were 10 categories, each with one first place winner. This only allowed 10 top winners out of 200,000 entrants, odds of winning: 1 out of 20,000 original entrants. However, in that contest, 9 out of 10 people didn't even complete the contest, which brings the odds for taking first down to 1 out of 2,000.

By the sheer fact that I stuck with the contest from start to finish, I moved ahead of 180,000 people, into the top 10 percent. Only by being in that top 10 percent did I have a chance to win at all. I can only assume that the dropout rate for other contests is similarly high. Therefore, making it to the top 10 percent can be a motivational force in making a commitment to not just enter a contest, but to stick with a program and complete it.

As in any race or contest, I believe you should enter with the intent to win. The first step when taking on any kind of commitment such as this should be to analyze and decide what winning means to you personally. For some, winning means taking the whole enchilada and nothing less. There is no room for second or third, and it's all or nothing. If you are someone with this mindset, be sure you have counted the costs before entering and have determined that it isn't more than you can handle. If it's not, then absolutely go for it.

I tell people that if they are going to enter a contest, and intend to win, they will need to *sell their soul* to disciplined eating and working out for the next 12 weeks. It involves coming out of the gate at full speed, and having very little time for transitional workouts or eating plans. I tell my clients that they need to start and finish the contest with the intent to train, eat and think at a level similar to professional athletes.

When you look at some of the before and after pictures, you can see that many of the changes border on unbelievable, not the type of results you get from a slow 30 to 60 day transitional strength training and cardio program, or the kind of results you can expect without a complete overhaul in your eating habits. However, I need to point out again the importance of not making THE CONTEST the end all, subjecting learning and practicing lifelong fitness habits to second place. Don't make your 'All or Nothing' attitude turn your physical transformation into a 'flash in the pan' experience. I've seen too many people with this kind of mindset go back to their old habits after the contest was finished because they hadn't planned on making fitness a process for life.

For other people, to win a contest simply means starting and finishing the 12 weeks without throwing in the towel. It means achieving maximum fitness in minimal time while staying committed to an organized training program and enjoying the process. For as much as I encourage all my clients to enter to WIN, I also work hard to help people see that the best reason for entering a contest should be to improve their physical well being. Getting in shape, eating better, getting stronger, and looking better – this is the cake. Actually winning the contest should only be the icing. With strong egos and narcissistic dreams, this is easier said than done.

Demands of Contest Competitors

Competing in a contest with an enveloping desire to win takes the stamina and mindset of a professional athlete. The problem is that very few of us tote 'professional athlete' on our resume of life. For the average, non-genetically gifted contestant, the demands may need to become an all-consuming obsession, and the required stamina needed can throw some for a loop if they're not prepared.

The demand on one's time in training for a contest is an area that people usually don't give much thought to. Suddenly, things like working a normal job, parties, or simply going to the movies turn into major events that need to be navigated and planned. Arranging, cooking, and even finding the time to eat the recommended meals can be frustrating. Trying to squeeze in cardio and weight training between a 9-to-5 job, family obligations, getting enough sleep, and personal commitments can all but cause some people to give up.

It is imperative that a person takes into consideration that there will be drastic changes on how they choose to use their time while doing a contest. Being flexible, meticulously organized, and having an adaptable frame of mind will make this demand less stressful. When I participated in the EAS contest, I prepared my wife well in advance, letting her know that during the contest might not be the best time to paint the house or go on an extended family vacation.

The physical energy needed to successfully compete in a contest can be a major wake-up call, especially for someone with no previous training experience. My clients tell me that the first 2 weeks are the worst in terms of feeling any positive physical benefits kicking in. But by the 4th week, habits are forming, the body is changing, and most people begin to feel increased energy levels. However, the emotional energy needed to stay focused and charged up may be hardest to muster when you are juggling dozens of other areas in your life, let alone training for a contest. I think it very important to have someone that will offer support, even if just listening to your frustrations or holding you accountable to your initial commitment. In my case I had many conversations with knowledgeable people to help deal with obstacles. I also received tremendous support from my wife, who helped by taking on extra daily duties around the house until the contest was finished.

Another demand, that I'm sure affects quite a few people, is the financial. Supplements are not cheap. If you throw in the cost of a gym membership and/or hiring a personal trainer on top of that, the crunch can be significant. It depends on how far you want to go. You can easily jack up hundreds of dollars in tanning, workout clothes, professional photography, exercise accessories and equipment, etc., etc. While training for the EAS contest, I tried every way possible to keep financial costs low. I did all my workouts alone in the basement of my house, using a homemade power rack and second hand weights and equipment. Some might think that this training environment was very limited, but it did the job. I did not hire a personal trainer, instead I relied on my own experience, and any training information I could get from people who seemed to know what they were talking about. Use a little ingenuity and imagination, and the financial demand can be minimal. Over the last couple of years most of the transformation contests have slacked off on supplement requirements that can help keep the costs down.

Whatever 'winning' a contest means to you, one thing is for certain: you can walk away with achievements and a feeling of accomplishment that can be with you for the rest of your life. I believe that herein lies the greatest tragedy of physical transformation contests – when people base the value of their involvement on their final placements as winners or losers.

The incredible transformation that people can make in such a short time is gloriously commendable. I believe that to give any lasting meaning to these contests, people must plan for what happens after the contest is over. Overall demands do not have to stay the same – although they can. Transition needs to occur, or you run the risk of being worse off in the end than you were in the beginning. For people participating in contests, it is crucial that they get into a 'normal' training and eating schedule once the contest is over. People need to realize that life is full of opportunities, bodily transformation being only one.

The results gained from entering a transformation contest should be there to stay. They should instill at least some habits for life. That's a whole other area worth discussing later. But for now, if you are one of those people considering entering a contest, I encourage and commend you for taking the challenge. I think the spouse of a former client said it best: "When the contest is over, win or lose, you still get to keep the body."

H. I. T.

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Chapter 5

Increasing Exercise Demands with Set Variables

With modest exercise experience, it quickly becomes obvious that there are only so many ‘good’ exercises, i.e., exercises that feel effective and preferred… or are effective. It also becomes obvious that, eventually, the body adapts to the same exercises performed in the same manner, and that the mind becomes stale and less motivated to exercise from doing the “same old.” For this reason, set variables are a viable contribution to increasing diversity and exercise demands, to help maintain motivation and stimulate further progress in strength and muscular size. By subjecting the neuromuscular system to a “unique” form of strain, thereby changing the “nature” of the stimulus, it is possible to “surprise” the muscles to a new level of function and development.

The major drawback of set variables is the increased likelihood of overtraining because of greater inroads into functional and recovery ability. Although our bodies require intense strain to stimulate potential results, many trainees do overtrain and adding variables frequently complicates matters. Keeping overall sets to a manageable number will help in avoiding an overtrained condition, but trainees also should avoid:

1. Implementing too many variables within each workout.
2. Implementing too many variables per body part in a workout.
3. Implementing too many variables within each set (combine two within a set only after realizing the effects of each variable).
4. Implementing variables for several consecutive workouts without a layoff from the variables.

Moreover, since the purpose of set variables is to help *disrupt homeostasis* and *adapt* muscles *forcibly* into further growth and function, it is best to deploy *some* of them on an infrequent basis, particularly the more demanding variables such as negative-only and forced repetitions. Also, set variables performed too often may result in an over-stimulus, and even *desensitization*. Consequently, use set variables sparingly, like a trump card, and only when necessary to give exercise an added "challenge."

Lastly, although about twenty set variables exist, those described below (in alphabetical order) are most applicable and used in a high-intensity training environment.

Descending Set

1. Choose a resistance that allows an appropriate time under tension (TUT), training to the point or close to muscular fatigue.
2. Reduce the resistance by 20-30% and train close to or to the point of muscular fatigue.
3. Continue "stripping" the weight for the desired number of mini-sets.
4. Maintain minimal rests (5-10 seconds) between mini-sets.

This is an excellent variable if the trainee finds it difficult to "feel" a muscle work hard. The added blood engorgement and burning sensation that occurs with multiple sets enhances the mind/muscle connection. Each mini-set should be relatively brief since each adds to the total in TUT.

Forced Repetition

This variable requires the assistance of an instructor for most multi-joint movements, but it is possible for a trainee to assist himself or herself on most single-joint movements, particularly when exercising on machines.

1. Perform a set to momentary muscular fatigue.
2. Have a training partner or a free limb assist the working muscles with an additional repetition.
3. Make certain the working muscle performs most of the work and at the same velocity as the previous non-assisted repetitions to maintain cadence consistency.

Adding forced repetitions to a set prepares and adapts the muscles for the new repetition limit. For example, 8 strict repetitions + 1 forced repetition informs the muscles that 9 repetitions are possible (or that the muscle must become strong enough to complete 9 repetitions in the future).

Isometrics

Assisted Isometrics

1. Use about 90% of a usual exercise load.
2. Have a training partner apply downward pressure at the sticking point to prevent the completion of each repetition (in essence, the training partner is replacing the pins in the power rack [see power rack isometrics above]).
3. Fight the resistance at that point for 3-5 seconds.
4. Complete the repetition for the remainder of the ROM, if desired.
5. Repeat steps 2-3 for the required number of repetitions.

Self-contained Isometrics

1. Complete a full ROM on every repetition but hold the resistance at the sticking point for 2-3 seconds during each repetition. The trainee can also perform multiple isometric holds throughout the full ROM, moving in 2-4 inch increments.
2. Complete for the desired number of repetitions.

Generating a high level of intensity by way of isometrics at a specific point in a ROM helps to improve strength increases at that point. Isometrics are particularly helpful in increasing strength and overcoming mechanical disadvantage at sticking points. It is typical and expected of trainees to hold their breaths to some degree during isometrics. Consequently, avoid this variable if the trainee suffers from hypertension or is unable to facilitate proper breathing.

Always, however, avoid holding the breath for long periods while exerting. Holding the breath can create a forcible exhalation against the closed glottis (a space between the vocal folds in the larynx), and this can increase intrathoracic pressure, impeding venous return to the heart, thereby causing fainting to occur. This phenomenon is termed the Valsalva maneuver. Attempt to exhale whenever possible during any type of exertion.

Negative Repetitions

Supplementary Negative Repetitions

1. Perform a set of any exercise approaching momentary muscular fatigue.
2. Once having reached fatigue, help the trainee lift the resistance to the top position, at the point of contraction.
3. As slowly as possible, the trainee is to lower the resistance to the bottom, stretched position.
4. Continue steps 2-3 for no more than 3-4 repetitions or until the cadence cannot sustain at least five seconds in duration.

Pure Negative Training

1. Utilize approximately 30-40% more resistance than what typically is used when lifting both up and down (for example, use 130-140 pounds for 8 repetitions if 100 pounds for 8 repetitions is usual).
2. The instructor will assist as much as possible to lift the resistance to the starting position (exercises like dips and chins allow the trainee to jump or climb into position without the aid of the instructor).
3. As slowly as possible, the trainee lowers the weight under control, with each repetition lasting at least 5 seconds, and preferably 7-10 seconds.
4. Repeat steps 2-3 until the cadence cannot be retained for the desired eccentric cadence – DO NOT continue the set until downward movement can no longer be controlled since doing so dramatically increases muscular inroading, thereby increasing the risk of overtraining and possibly injury if the weight drops rapidly.

Forced Negative Repetitions

1. Utilize about 10-20% less resistance than usual.
2. The trainee will lift the weight to the contracted position as usual.
3. The instructor then pushes down on the resistance to increase eccentric overload.
4. Once at the bottom position, the instructor will discontinue adding pressure so that another concentric repetition may be performed. The amount of force applied during the eccentric may need to vary, depending on the leverage and force curve of the exercise.
5. Repeat steps 2-4 until approaching concentric muscular failure, making certain that each negative repetition is at least 5 seconds.

Alternating Uni-Lateral Negative Repetitions

1. Perform an exercise that allows both bi-lateral & uni-lateral training (e.g., leg extension, calf raise, or machine press).
2. Raise the weight with both limbs.
3. Lower the weight under control with only one limb, making certain each rep lasts at least 5 seconds, and preferably 7-10 seconds.
4. Raise the weight with both limbs for another repetition.
5. Lower the weight under control with the *opposite* limb.
6. Continue steps 2-5 until the cadence cannot be maintained for the desired cadence.

*** ***

Eccentric-only exercise has many uses. Obviously it can create a greater muscular inroad in a much briefer period, thus making it ideal for increasing strength and size if not abused. It also is ideal for those too weak to lift even one plate on some selectorized weight lifting equipment or for those unable to perform any positive repetitions in the chin-up, sit-up, and dip exercises. Some people are unable to train hard, and they find exercise that approaches muscular fatigue uncomfortable. Similarly, those recovering from an injury find exercise rehabilitation painful or uncomfortable and negative-only exercise does not produce the same level of "burn" or pain associated with regular exercise that include both concentric and eccentric movement.

It should be obvious the importance, or at least the value of eccentric exercise in different instances. Furthermore, since overload is limited by the amount that can be lifted concentrically during regular exercise, there may be value in limiting the amount of concentric exercise in order to maximize the strength and size potential that eccentric exercise can provide.

There are several ways to utilize eccentric exercise, as explained above. The overload value of the uni-lateral negative rep method should not be overlooked. To explain, if under normal conditions 200 pounds on the leg extension for 10 repetitions is possible, each leg would resist against 100 pounds. When lowering one leg at a time with 80% of a typical weight (160 pounds in this instance), the unilateral-negative method provides160 pounds of tension. This equates to a 60% increase in weight and an additional 600-pound total load over the course of the set (60lbs extra x 10 repetitions). This strategy clearly embraces the overload principle.

The most practical way to implement unilateral-negatives is with machines, e.g., leg extensions, leg curls, standing calf raises, biceps and triceps machines, pec deck and the Nautilus pullover, since balancing is not required. Dumbbells can be used for some movements, such as concentration curls and lying triceps extensions.

Forced negatives allow for a focus on the eccentric phase of the movement. This method is useful on nearly all exercise mediums including free weights and machines. When using barbells, make certain to apply an evenly distributed force to avoid loss of balance or over stimulation to one side of the body.

For those new to pure-negative (negative-only) exercise, it is necessary to break in slowly so as not to create a high alarm reaction from the extreme strain. Although this is true of any new training method or exercise, pure-negative exercise can cause extensive tissue damage and debilitating muscle soreness. On the first workout, use a resistance that will allow 3-4 *concentric* repetitions (but do not perform any concentric reps), and train short of *eccentric* fatigue; this means there will be complete control with energy to spare, even by the end of the set. Next workout, and with the same resistance, train to complete *eccentric* fatigue, to the point where the velocity of descent begins to increase from normal, e.g., when a 5-10 second cadence cannot be maintained. From this point onward, use a resistance that falls into one of the three categories, depending on the level of demands desired:

a) *Light resistance:* For the first 1-2 repetitions of the set there is sufficient strength to stop the movement (isometric hold) anywhere along its path, or even to reverse directions concentrically if desired. Near the end of the set it should be impossible either to stop or reverse directions.

b) *Moderate resistance:* For the first 1-2 repetitions of the set there is sufficient strength to stop the movement anywhere along its path, if desired, but directions cannot be reversed, even if tried. Toward the end of the set it should be impossible to stop the movement.

c) *Heavy resistance:* From the first repetition, the movement cannot be stopped or directions reversed, even if tried.

When first attempting negative exercise, the weight should be in accordance to a light resistance, as described above. After a few workouts, move up to a moderate resistance. Advanced negative implementation can include a heavy resistance, but only when the mind and muscles are prepared fully. For maximum strength and size gains, the last two categories will yield the greatest results, but caution and adequate preparation (warm-ups) are a must to avoid injury. In all instances, the resistance must be lowered in a slow and deliberate fashion. Perform approximately 8-10 repetitions at a cadence of at least 5-6 seconds; and once capable of 10 controlled repetitions, increase the load.

It is important to maintain a relatively slow cadence, of at least 5-6 seconds, and the set should terminate once movement accelerates. Otherwise, the risk for injury increases significantly because of a high rate of kinetic energy, followed by a high force at the stretched position of an exercise.

When performing negative training, do not rest at the top of a movement. Once the resistance is raised into place, immediately begin lowering it. Even a slight pause at lockout allows muscles to recover partially.

A final tip is to make certain the resistance is "handed over" to the working muscles in a smooth, deliberate manner. The helping limb or training partner(s) must not jerk, jar or drop the resistance to the awaiting muscles; otherwise injury may occur. Consequently, it is beneficial to have the working muscles help make the concentric lift to some extent, rather than relax completely between eccentric attempts.

One-Repetition Method

1. Use a resistance that allows only one repetition close to or at the point of muscular fatigue.
2. Take 30 seconds to lift or lower a resistance (if the concentric was performed first, this makes the variable easier, since concentric ability is reduced too much if the eccentric was performed first).
3. Take 30 seconds to reverse directions, to either lift or lower a resistance.
4. If steps 3 and 4 can be accomplished, the resistance can be increased appropriately.

This variable is ideal for concentrating on technique, feel, and isolating muscular contraction. It is also appropriate for rehabilitating an injured body part. One problem that may be encountered, however, is that some people do not have very good motor control or efficiency, and this results in repetition segmentation of short blocks of movement interspersed with brief isometric holds. In other words, the weight moves up a bit, then stops, then movement continues and stops, etc.

1¼ Method

1. Lift a resistance to the point of contraction or stretch (depending on where the most difficult part of the exercise happens to be, e.g., leg extension = contraction, or pec deck = stretch).
2. Lower the resistance ¼ way and then lift the resistance back up to the point of contraction or stretch.
3. Lower or lift the resistance for another full movement.

Trainees can duplicate and triplicate the quarter rep segment, i.e., perform 2-3 quarter reps at the point of contraction or stretch before continuing for another full movement.

Overloads

Forced Overloads

1. This variable requires the use of an instructor or free limb (as described in the bottom paragraph).
2. Utilize a resistance approximately 80% of a regular training load (not 80% of a 1 RM).
3. Commencing with the first repetition, the instructor provides enough resistance on the eccentric phase of the movement to make it rather difficult, but not impossible (total control of the eccentric phase is necessary to avoid injury and to ensure muscle stimulation).
4. The instructor continues to apply resistance while performing the concentric half of the repetition. The instructor should provide enough resistance to make each repetition a *near-maximum attempt*.
5. As the repetitions proceed, and fatigue increases, the instructor will need to apply progressively less pressure to the load. Aim to achieve 5-6 slow repetitions.

Maximum Overloads

1. Utilize a near-maximum load for the entire set.
2. Commencing on the second repetition, the instructor helps lift the load only enough to make each repetition a difficult attempt.
3. The eccentric phase should be as slow as possible and the set should terminate once the weight cannot be lowered in at least five seconds.
4. With the exception of the first repetition, all other repetitions will be forced (assisted) repetitions — do not exceed 4-5 repetitions total for any set because of the extreme demands of this variable.

For safety reasons, it is best to implement this variable on machines. Free weights increase the risk of injury as a result of balancing and coordinating the resistance. There are some exceptions, such as the concentration curl for the biceps brachii, but this variable should be avoided with highly precarious exercises such as the squat.

It is possible to use a free limb as a spotter with many unilateral exercises to help the working limb lift a weight, such as with concentration curls, leg extensions, single-legged calf raise, and cable triceps pushdowns.

Partial Repetitions

Bottom Range Partials

1. Utilize approximately 90% of a usual training load.
2. Move the resistance only through 2/3 of the most difficult range (at the point of stretch) of an exercise.
3. Complete the set close to or at the point of momentary muscular fatigue, and attempt one full movement on the final repetition.

Top Range Partials

1. Choose a weight that is approximately 30-60% heavier than usual (the amount will depend on the magnitude of the range-of-motion and the leverage advantage/disadvantage of the exercise).
2. Move the resistance only through the strongest 1/4 to 2/3 of the range of motion.
3. Complete the set close to or at the point of momentary muscular fatigue.

Pre-Exhaustion

1. Perform the required number of repetitions of single-joint movement to the point or close to momentary muscular fatigue.
2. With as little rest as possible (<15 seconds), perform the required number of repetitions of a multi-joint movement until having reached or close to the point of momentary muscular fatigue.

By first exhausting the target muscle with a SJ movement (an exercise that does not overly involve another muscle), a trainee can further exhaust that muscle by following up with a MJ movement that requires the assistance of other body parts. With the other muscles being “fresh”, and the target muscle fatigued, the assisting muscles help to create deeper inroads for a greater net effect.

Examples of pre-exhaust combinations include pec deck + chest press or dip, pullover + pulldown or chin, leg extension + leg press or squat, lateral shoulder raise + overhead press. This method of pre-exhaustion is called **assistant pre-exhaustion**, since the smaller muscles work in a MJ movement to further fatigue the larger muscle, e.g. pec deck + bench press result in the triceps and deltoids helping in the MJ exercise to further fatigue the pectorals.

A second method of pre-exhaustion is called **reverse pre-exhaustion**, wherein a larger muscle in the MJ movement helps to further fatigue a smaller target muscle, e.g. barbell curl + chin-up results in the lats assisting the biceps brachii.

Static (+Negatives)

1. Version 1: Select a movement that allows for an intense peak contraction, such as the leg extension. After exercising to the point or close to concentric fatigue, hold the last repetition at full contraction for as long as possible before slowly lowering the resistance to complete the set. The trainee should increase the weight if the static repetition can be held for more than 20-30 seconds. Keep in mind the total TUT when *adding* a static hold to the end of a set.

2. Version 2: The second method requires a trainee to avoid performing several regular repetitions, commencing the set immediately with a static hold. Select a weight that is 20% heavier than a usual exercise load and hold it for as long as possible before lowering slowly to complete the set. Hold for an appropriately time and increase the weight when needed.

Ideal peak contraction exercises for static hold implementation include lat pulldowns, calf raises, leg extensions, lateral raises, rows, machine curls, machine triceps extensions, machine pullovers, standing leg curls, machine abdominal crunches, and pec deck flyes.

Stutter Repetitions

1. Use approximately 75% of a usual weight.
2. Raise the weight one-third way.
3. Lower the weight back one-fifth way.
4. Repeat steps 2-3 to full contraction, as if to move the weight “two-steps-forward-and-one-step-back.”
5. From the contracted position, lower the weight to the starting point in one continuous movement *or* repeat the stutter pattern for the eccentric phase of the repetition.
6. Continue close to or to the point of muscular fatigue.

This is an excellent variable if the trainee finds it difficult to “feel” a muscle work hard. The added blood engorgement and burning sensation that occurs with multiple sets enhances the mind/muscle connection. This variable works best with broad-ROM exercises, like the pullover, pulldown, or leg extension. Short-ROM exercises, e.g., calf raise, wrist curl, do not provide enough distance to warrant stutter repetitions, or makes it difficult to execute the variable properly.

Twenty-one Method

1. Use approximately 60% of a usual weight.
2. Perform 7 half repetitions, from the stretched position to the halfway point.
3. Perform 7 half repetitions, from the halfway point to the contracted position.
4. Perform 7 full ROM repetitions.

The above totals 21 repetitions (hence, the name), an arbitrary number. The values could easily be 5/5/5 or 3/3/3, but 21 was selected and coined. The total measure of reps and TUT, however, should coincide with an appropriate cadence and tension time. For example, if a full repetition lasted 5 seconds positive, then each half-rep would be approximately 2 seconds up and 2 seconds down. Therefore, 5 bottom half-reps (20 seconds), followed by 5 top half-reps (20 seconds), followed by 3 full reps (30 seconds) would total 70 seconds tension time.

This is an excellent variable if the trainee finds it difficult to "feel" a muscle work hard. The added blood engorgement and burning sensation that occurs with multiple sets enhances the mind/muscle connection.

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Chapter 6

High Intensity Training Case Studies & Research

It was not until the early 1970s that the concept of brief, intense training was studied, i.e., how effective was training to muscular fatigue, how much was required of such exercise, and what changes would occur to the body, including those related to strength, muscle mass, flexibility, and cardiovascular efficiency. This chapter looks at the various experiments conducted by Arthur Jones and colleagues, and some of the popular physique stars who have used high-intensity training successfully.

DeLand High School

Prior to 1972, DeLand High School, in Florida, never had a weight room. Arthur Jones equipped the high school with various free weights and some early Nautilus machines. Shortly after that time the high school put together a weight lifting team and competed State wide in the bench press and clean & jerk.

Over five years and 100+ meets, the Deland High School weight lifting team was undefeated. How did they exercise? They performed two weekly workouts that consisted of one set of each exercise for 6-8 repetitions of negative-only exercise. The team occasionally practiced the bench press and clean & jerk in order to maintain and improve upon the specific skills required, but developed their strength primarily with negative-only exercises that were non-specific to the two competitive lifts. This philosophy was followed since it was believed, and rightly so, that there is a difference between developing strength and demonstrating strength.

After five years of being undefeated, coach Bradshaw retired, and was replaced by another coach who re-implemented traditional weight training methods… and who continued to lose competitions thereafter.

The Colorado Experiment

<u>Date</u>: May 1, 1973 through May 29, 1973, an elapsed period of 28 days. Total training time over 14 workouts was 7 hours and 50.5 minutes, an average of 33.6 minutes per workout.

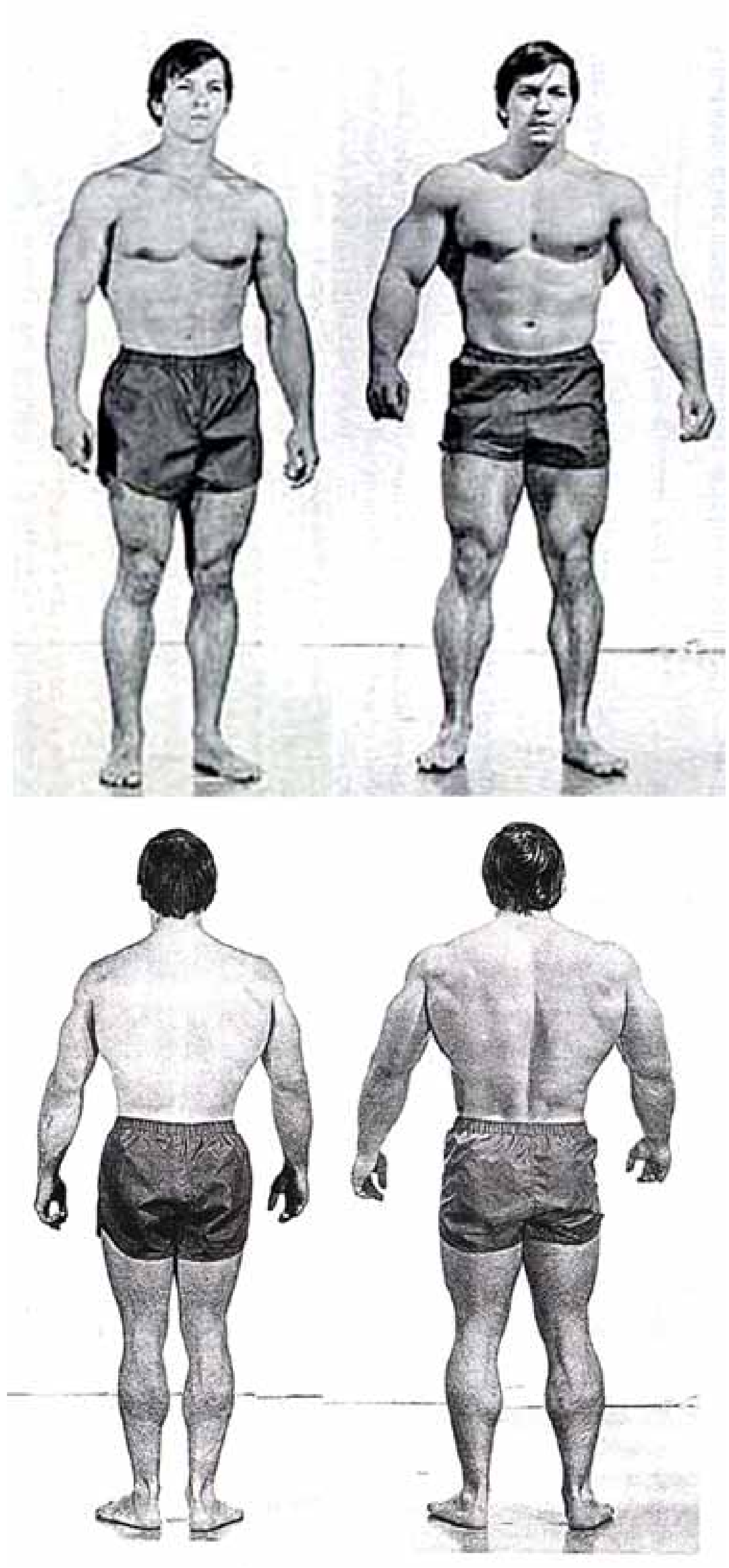
<u>Location</u>: Department of Physical Education, Colorado State University, Fort Collins, Colorado.

<u>Supervision</u>: Dr. Elliott Plese, Director of Exercise Physiology Lab., Colorado State University.

<u>Testing Method</u>: Lean body-mass and fat contents determined by the Whole-Body Counter under the supervision of James E. Johnson, Ph.D., Associate Professor, Department of Radiology and Radiation Biology, Colorado State University.

<u>Purpose of Experiment</u>: It was Arthur Jones' contention that the growth of human muscular tissue is related to the intensity of exercise; increases in strength and muscle mass are produced rapidly with very brief and infrequent training… if the intensity of exercise is high enough. Based on this premise, the Colorado Experiment's purpose was to see how quickly Casey Viator, a competitive bodybuilder could regain muscular size and strength after an illness and a dramatic loss of body weight.

<u>Results</u>: Increase of 45.28 pounds of body weight; a loss of 17.93 pounds of fat; a muscular gain of 63.21 pounds. In 28 days Casey Viator's weight changed from 166.87 pounds to 212.15 pounds.



In 28 days, Casey Viator increased his body weight from 166.87 pounds to 212.15 pounds, with a total of 7 hours 50 ½ minutes of exercise, or an average of 33.6 minutes of exercise over 14 workouts.

The Colorado Experiment, perhaps, was and still is the most legendary and talked-about clinical investigation in the history of exercise science. Primarily, it proved once and for all that dramatic change in strength and lean muscle mass could take place in a nontraditional setting, i.e., a very brief and intense exercise program. It also put another nail in the coffin for those who deemed long (2+ hours) and frequent (5+ days a week) workouts necessary.

During a 28-day period of the Colorado Experiment, supervised by Dr. Elliott Plese, Director of Exercise Physiology Lab, Department of Education, Colorado State University, Casey Viator gained a total of 63 pounds of lean muscle by performing only 14 workouts using Nautilus Training equipment (and mostly negative-only or negative-accentuated exercise). Total training time was only seven hours, fifty and one-half minutes... an average of 33 minutes and 36 seconds each workout.

Lean body mass and fat content determinations were produced by the Whole-Body Counter under the supervision of James E. Johnson, Ph.D., Associate Professor, Department of Radiology and Radiation Biology, Colorado State University. It was concluded that Viator increased his bodyweight by 45.28 pounds, yet dropped his fat by 17.93 pounds, for a total muscular gain of 63.21 pounds.

Prior to that experiment, Viator already had attained a very muscular body, having won the Mr. America at age 19 in 1971, by using both free weights and Nautilus machines. From September of 1972 until December 23, 1972, he trained exclusively with Nautilus machines… limiting his exercises to 'negative-only' movements. At the end of that period he weighted 200.5 pounds. In early January 1973, Viator was involved in a serious accident at work and lost most of one finger as a result, and almost died from an allergic reaction to an antitetanus injection.

For approximately four months, most of January through April of 1973,he did not train at all; and since his level of activity was low, his diet was reduced accordingly. During that period he lost 33.63 pounds, but 18.75 pounds were lost as a direct result of the accident and the near-fatal injection (an eventual weight of 166.87 pounds). And so Viator's loss from nearly four months out of training was only 14.88 pounds, less than one pound per week.

It was concluded that Viator could once again reach his former bodyweight in a very brief period while incorporating high-intensity exercise; which experiment lasted less than one month.

During the first 14 days Viator gained 28.93 pounds, a daily average of 2.06 pounds. During the next 3 days he gained 3.92 pounds, a daily average of 1.3 pounds. He continued to gain regularly during the entire 28-day period, while averaging 1.05 pounds per day during the final 6 days. This data suggests that his rate of gain was slowing down, but his actual growth rate was steady. Viator did not have to produce strength in order to produce size... it happened concurrently. If the reader were to break down Viator's workouts, it would be discovered that he averaged 4.51 pounds of muscle mass increase per workout… or .36 pounds per set... an average gain of 8.04 pounds from each hour of training! And since there were no sudden growth spurts, weight gain could not be attributed to super-hydration practices.

Viator's strength gains also were dramatic. On the first day his strength was tested on a Universal Machine. He performed 32 repetitions in the leg-press with 400 pounds. Twenty-eight days later, having done nothing that resembled a horizontal, Universal leg press, he performed 45 repetitions with 840 pounds. Viator was forced to quit at that point due to pain, not muscular (mechanical) fatigue. His other strength increases also were quite dramatic, such as chins for 7 reps with 217 pounds (including bodyweight), then eventually 11 reps with 287 pounds.

The pace of the workouts was quite fast, with very brief rests between some exercises. Viator performed each exercise to positive muscular fatigue, mostly for one set only, except for the negative-only exercises, which were carried to the point of being unable to control the descent of the resistance.

Both forced reps and negative reps were integral components of the experiment. Viator had many people to assist in forced reps and spotting. He also had access to many of the prototype machines with self-spotting devices, and so spotting and lifting the resistance for negative-only exercise or forced repetitions were possible without assistance from others.

In general, approximately ten repetitions were performed in each set; but in all cases, the maximum possible number of repetitions were performed… stopping only when it was impossible to perform another repetition in good form. The 'form' or style of performance was as strict as possible, the resistance was moved in a smooth fashion, and was stopped briefly in the position of full muscular contraction. Jerking and sudden movements were avoided completely.

There was no cardiovascular work performed, with the exception of walking to the facility to train. Cardio work was unnecessary since Viator's heart rate increased to 180 beats per minute. In the first week his pulse rate went to 200 beats per minute and he would lay purple on the floor. He had trouble trying to acclimatize to the mile high altitude as compared to Florida's sea level elevation, and so, in the beginning, it was quite a struggle.

Interestingly, although he gained a lot of muscle quickly, he also improved his flexibility. To quote Arthur Jones, who was part of the Colorado Experiment:

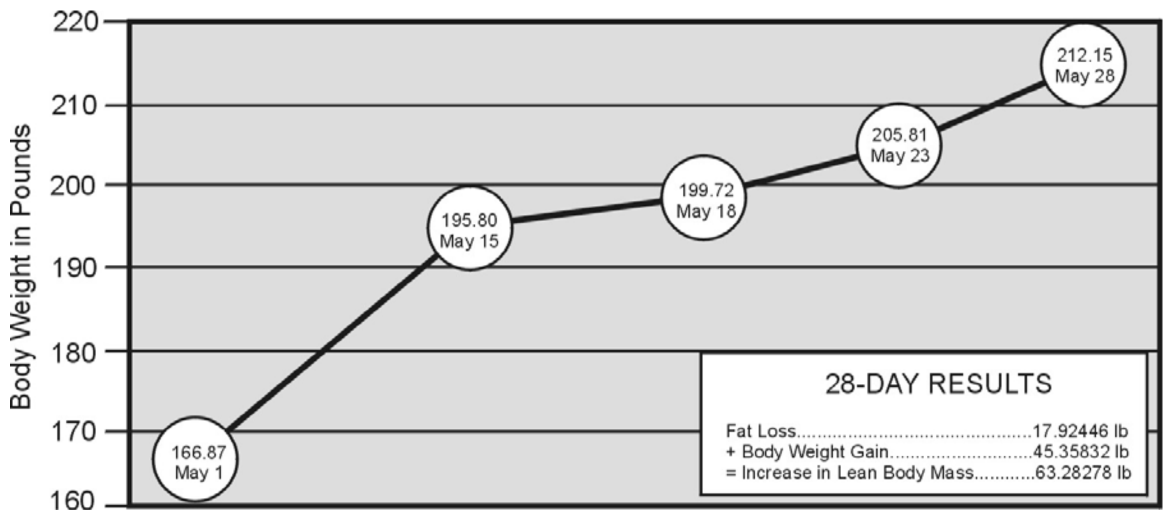
"Flexibility? Near the end of the experiment, at a bodyweight of over 200 pounds, this subject clearly demonstrated a range of movement far in excess of that possible for any member of the Colorado State University wrestling team. In fact, his demonstrated range of movement was so far in excess of average range of movement that it literally must be seen to be appreciated... clearly proving that great muscular size does not have to limit flexibility, if it is produced by exercises that provide full-range movements."

Neither did Viator incur any injuries during that intense training period. His joints were not overworked and everything was done in strict form to prevent injury. He did get food poisoning one week into the experiment and with a full belly of food; a doctor was called in because time was of the essence in the experiment. He recovered and resumed hard training.

Viator also rested a lot between training sessions to gain that amount of weight in only 28 days. He averaged 10 hours sleep per day with a nap in the afternoon before training; workouts that were both legendary in their intensity and not something that is appropriate for most people (but which serves as an example of the effectiveness of quality vs. quantity). Evidently, a person would have to be very motivated and of superior genetics to obtain this kind of weight gain in such a brief period.

Viator's diet was based on whole foods, although he did include some egg and milk protein powder. No other supplementation was needed since he was eating such a well-rounded diet, consisting of 400 grams of protein daily (on average), mostly from lean chicken, lean red meats, fish and low fat dairy products. Viator believed that he overdid the protein intake, but the excess was expelled nonetheless. He kept his total carbohydrate intake to 50% and his fat intake around 15% of total consumption.

Lastly, it should be noted that no anabolic steroids of any kind were used in the Colorado Experiment experiment.



The West Point Study*

Overview

In 1975, a critical study was conducted on the effects of brief, high-intensity exercise on Nautilus machines. The results were both impressive and clearly indicated that there was little need for long workouts in the gym, or even for aerobic-based exercise to improve heart and lung function if strength training were implemented properly.

The overall results included a 59% increase in each of 10 exercises (over 6 weeks and 17 workouts), whereas the free weight control group should little change. For the two-mile run, the Nautilus group improved by 88 seconds on average and with no running in the program, whereas the other group (which did include running) only improved by 20 seconds on average. Flexibility increased by 11% on average in three measures with the Nautilus group, whereas the control group increased by only 1%. Moreover, although cardiorespiratory results were measured and controlled by a team from the Cooper Institute, the changes made in the Nautilus strength-training group were so remarkable that Dr. Kenneth Cooper refused to believe the results; could not believe that non-aerobic-based exercise could achieve such changes in such a short period.

Background

Since the early 1800s, a mission of the US Military Academy has been to select, train, and educate the finest of Americans, with one factor to that mission being to insure each graduate possesses the physical qualities necessary. To achieve this objective, each cadet is required to participate in a fitness program designed to improve/optimize physical conditioning, followed by regular examinations and evaluations on his or her status. Because of this commitment, the Academy at West Point decided to undertake a comprehensive study of strength training and its consequences.

More specifically, the Academy wanted to determine how to utilize more effectively Nautilus strength training equipment that it had purchased in early 1975. With the assistance of Col. James Anderson, Director of USMA's Office of Physical Education, representatives of Nautilus Sports/Medical Industries, Project Total Conditioning was developed, to provide USMA with the institutional knowledge of how to use its Nautilus equipment properly; to examine the relative effectiveness of different methods of strength training; and to identify the consequences of a brief, high-intensity protocol.

USMA was looking for several answers to important questions. Can substantial strength gains be obtained from intense and brief workouts? What effect does strength training have on a person's cardiovascular fitness, on flexibility, and overall body composition? How often should a person train to obtain maximum results or benefits? What effect does high-intensity exercise have on functional performance, i.e., activities outside the weight room? In sum, Project Total Conditioning became the most productive and inclusive field research endeavor ever embarked upon in the area of strength training.

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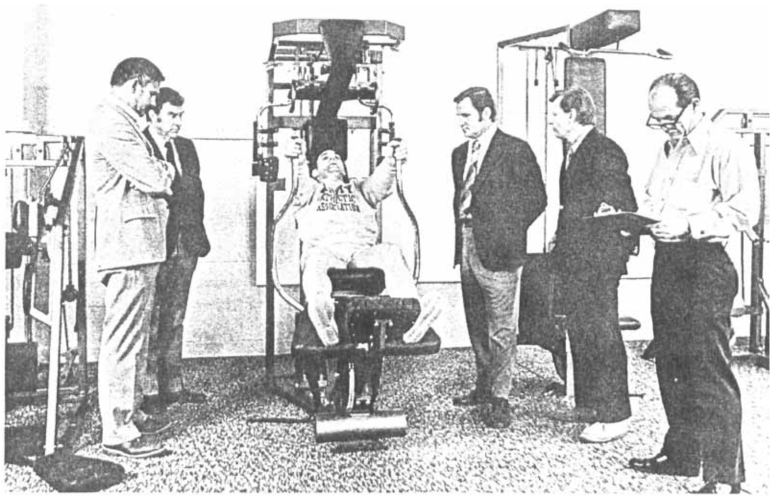
* This section adapted from the report Total Conditioning: A Case Study, written by James E. Peterson, for *The Athletic Journal*, Vol. 56, September 1975.



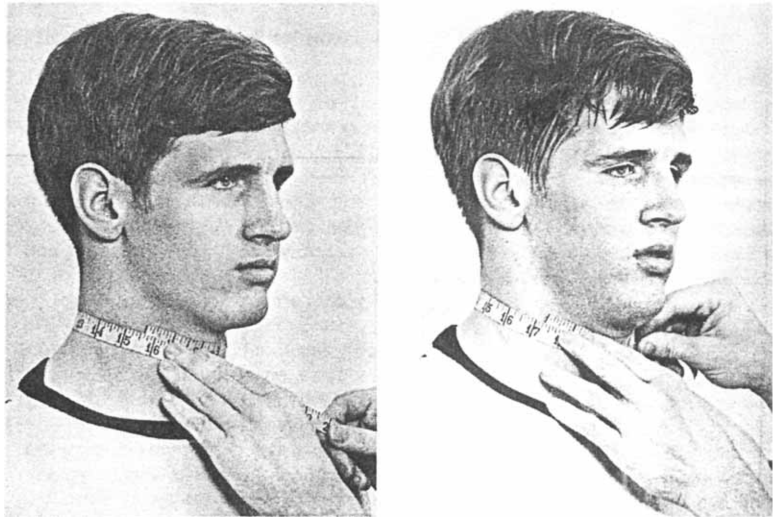
Major Alfred Ruschatz using a Nautilus Double Chest Machine. Observing: (left to right) Dr. Fred Jackson, neurosurgery; Prof. Stanley Plagenhoef, biomechanics; Coach Don Shula, Miami Dolphins; Dr. Robert Nirschl, orthopedic surgery; Arthur Jones, Nautilus Sports/Medical Industries.

Subjects for this research included members of the Corps of cadets, all without a history of recent illness or debilitating injuries. Moreover, both consultant physicians and Army Hospital physicians monitored all activities in the project, while Academy personnel controlled all pre- and post-training testing to insure validity and objectivity.

To make best use of as many personnel as possible, several studies were conducted concurrently. The primary investigation involved 19 subjects who were varsity football players, known as the 'wholebody group' since they performed full-body training each session. A matched control group of collegiate football players were chosen for comparative purposes. The wholebody group trained under very controlled conditions for 8 weeks, and three times each week.

To identify and evaluate any changes made during the project, several tests and measurements were made to every member of both groups after the wholebody group trained for two weeks and at the conclusion, at eight weeks. The pre-study testing was not conducted until after the initial two weeks to account for the influence of what is known commonly as the "learning effect" on individual performance, when a person experiences dramatic neurological increases in performance or ability because of rapid adaptation to new equipment or training methods. The pre- and post-training between-group differences then provided the basis for evaluation of the training effects.

Another study examined the effects of multi-functional, bi-lateral neck-strength training, whereby 16 varsity football players engaged in a neck strengthening program using only three Nautilus neck machines. The results of the subjects were compared with those achieved by a control group, whose members participated in a semi-supervised neck strengthening program that included isometric exercises devised by the USMA football staff.



"Cold" measurement of a subject's neck immediately before a brief but hard workout on three types of Nautilus Neck Machines. Less than 8 minutes later, a second measurement indicates an enormous increase in the subject's neck size. While temporary, such an increase clearly indicates the effectiveness of the exercises.

Two secondary studies involved members of the Academy's club squad rugby and volleyball teams. The rugby team members were involved in a study designed to determine the effects on overall neck strength of a twice weekly as opposed to a three-times weekly workout protocol. In the second project, 22 volleyball team members participated in a comparison of the effects on vertical jumping ability of a strengthening program between the Nautilus regular hip and back machine relative to one that used the Nautilus DUOsymmetric POLYcontractile hip and back machine.

In order to discuss the results of these studies, Project Total Conditioning has been divided into six sections: 1) strength training; 2) neck strengthening; 3) cardiovascular fitness; 4) flexibility; 5) body composition; and 6) concurrent studies.

Results

Strength Training

For several decades, two of the most widely debated aspects of strength training include the intensity of effort of exercise and the length of time one should devote to exercise. In the first study of this project, 19 subjects trained three days a week on alternate days, with a two-day rest after the third workout, for eight weeks. Each workout was relatively brief as subjects moved from one exercise to the next very quickly with minimum recovery time between exercises. Initially, some subjects became nauseated, but within a few weeks all 'negative' effects of such severe exercise disappeared and the time to complete each workout decreased considerably. A typical workout consisted of ten basic exercises, although twice a week the wholebody group included six exercises to strengthen the neck. Table 1 lists the different exercises included, and in varying combinations that constituted the training program.

Table 1. Exercises and machines used in Project Total Conditioning

EXERCISE	MACHINE	EXERCISE	MACHINE
1. Leg Extension	Compound Leg	11. Seated Press	DUO-Shoulder
2. Leg Press	Compound Leg	12. Double Chest	Double Chest
3. Squat	Leg & Back	13. Decline Press	Double Chest
4. Hip and Back	Super Hip & Back DUO-POLY Hip & Back	14. Biceps Curl	Curl-Triceps DUO-POLY Curl
5. Leg Curl	Leg Curl	15. Triceps Curl	Curl-Triceps DUO-POLY Triceps
6. Pullover	Pullover	16. Neck Extension	4-way Neck
7. Bench Press	Infimetric Bench Omni Bench	17. Neck Flexion	4-way Neck
8. Chins	Multi-Exercise	18. Bi-lateral Neck Flexion	4-way Neck
9. Dips	Multi-Exercise	19. Shoulder Shrug	Neck & Shoulder
10. Torso Arm Pulldown	Torso Arm	20. Rotary Neck	Rotary Neck

Three different ways to exercise were prescribed. In the first method, an exercise was done in ‘normal’ fashion, whereby the subject both lifted and lowered the weight under his ability. In the second method of exercise, a movement was performed in ‘negative-accentuated’ fashion, whereby the subject lifted the weight with both limbs and lowered the weight with one limb, and performed alternatively. With this method of exercise, a greater amount of weight can be lowered with the one limb, which increases the extent of overload. In the third manner of exercise, subjects employed ‘negative-only’ exercise, whereby a weight was lifted by assistants and the subject lowered the weight at a controlled pace. This method greatly increased the amount of load on the muscles since a person can lower more weight than can be lifted (in effect, with a ‘normal’ style of lifting, the amount of weight that can be lowered is limited by how much weight can be lifted).

Training procedures were controlled precisely, as each subject in the wholebody group worked out at a scheduled time and on a one-to-one basis with a supervising personnel. A record of each workout was kept for each subject, including the exercises performed, the amount of resistance, and the number of repetitions for each exercise (as well as any extraneous information, such as illness).

The initial amount of resistance for each subject was prescribed arbitrarily, based on what the staff believed each person could handle. Interestingly, although most of the 19 wholebody group members had trained with weights prior to the project, each subject developed extreme muscle soreness, which dissipated by the fourth workout.

Having developed the basic parameters of how to proceed, the remaining matter of concern was how to measure accurately changes in strength; the problem was based on the concept of ‘strength,’ i.e., the precise determination of expression that can vary relative to the conditions in which it is employed. Two of the dominant conditions included: 1) the mechanical advantage produced by the body's system of levers, and 2) the influence of neurological factors. First, since muscular contractions express force through movement of skeletal levers, the end product is a measure of torque rather than force per se. Consequently, the position of levers involved in a specific exercise is important. The angle of attachment affects a muscle's strength and its resultant mechanical advantage. For instance, with all other factors remaining equal, a person with short arms can biceps-curl more weight than a person with longer arms because of a mechanical advantage of a shorter lever.

A second complication in strength measurement for this project was that muscles respond to stimulation from the nervous system and, as a result, maximum volitional strength is affected significantly by neurological factors (which aspect also include psychological factors, such as motivation; fortunately, members of the Corps of Cadets were a highly motivated and disciplined group). Regrettably, it is difficult to quantify the influence of these factors. Nonetheless, it has been suggested that if a reasonable amount of training is provided for an initial learning effect to accrue, as was done with this project, then absolute strength can be measured by way of a tensiometer. The other method would be to measure an individual's ability to lift an increased amount of weight for about the same number of repetitions of a given exercise (so long as the quality of performance was relatively the same). A third way to determine change would be based on a person's lean muscle mass, or an individual's ability to perform on a functional tool that involves strength (e.g., leg power) in an attempt to provide sufficient information on the consequences of the Nautilus strength training equipment. Project Total Conditioning incorporated all four methods to identify change.

A series of tensiometers (for the major muscle groups) were developed, instruments that measured the force an individual can exert at a particular joint angle. By way of an attached dynamometer, force was produced against a static resistance, with six machines designed to be compatible with the movement required in a Nautilus machine of comparable function: 1) bench press; 2) leg extension; 3) leg curl; 4) hip and back; 5) biceps curl; and 6) one for the four basic functions of the neck. Although the mechanical advantage of a tensiometer altered slightly from one subject to the next, it did not change for the individual himself, and the resultant pre- and post-measurements reflected a valid change since the angle remained constant from test to test for each subject.

However, problems arose in regard to the use of the machines, and the inaccurate data was discarded with the exception of data derived from the neck tensiometer. In this regard, other means of establishing change had to be considered. Tables 2 and 3 detail the nature of the changes, by comparing the average amount of weight that a subject used for identical workouts (i.e., the exercises performed, the order of exercises, and the relative intensity of the workout); one at the beginning of training, and the other at the conclusion of the 8-week period. The significance in change can be provided additional credibility when the two weeks of training that were allocated to 'learning' are considered.

Table 2: A comparison of the 1st and 17th workouts of the wholebody group subjects.

	1st Workout			17th Workout (c)			Net Change	
Subject (a)	**Ave Wt (10 exercises)**	**Ave # of Reps**	**Duration (b) (in min)**	**Ave Wt. (10 exercises)**	**Ave # of Reps**	**Duration (in min)**	**Ave Wt. (in lbs)**	**Change (%)**
1.	99.0	9.3	N/A	168.0	10.4	N/A	69.0	69.70
2.	80.5	6.7	49	135.5	9.2	25	55.0	68.32
3.	96.5	7.8	42	160.5	8.3	27	64.0	66.32
4.	93.0	8.0	43	154.0	8.9	22	61.0	65.59
5.	80.5	9.3	N/A	132.0	9.2	N/A	51.5	63.98
6.	91.5	7.3	29	149.0	8.7	21	57.5	62.77
7.	98.5	11.0	33	157.5	8.8	30	59.0	59.90
8.	101.0	9.7	44.5	161.5	10.7	35	60.5	59.90
9.	98.0	10.5	33	156.5	10.8	30	58.5	59.69
10. (d)	95.0	9.7	33	150.5	8.7	38	55.5	58.42
11.	94.0	7.9	N/a	147.5	10.0	N/A	53.5	56.91
12.	101.5	7.3	N/A	159.0	8.2	N/A	57.5	56.65
13.	88.5	9.2	35	137.5	9.0	29	49.0	55.37
14 (d)	89.5	13.7	34	138.5	11.4	30	49.0	54.75
15.	94.0	8.2	N/A	142.0	9.0	N/A	48.0	51.06
16.	104.5	8.6	N/A	157.0	10.4	N/A	52.5	50.24
17.	97.0	9.8	40	144.0	10.8	28	52.5	50.24
18.	85.5	9.1	N/A	124.5	11.5	N/A	39.0	45.81
Mean=	93.78	9.06	37.73	148.61	9.67	28.64	54.54	58.54

a. Arranged in rank order by achieved percentage of improvement. Only 18 subjects are listed even though 19 participated in the study because one subject was injured during football practice and subsequently was excused from some exercises.

b. Rounded off to the nearest half minute. N/A is used to designate those from whom no recording of the duration of their workout is available.

c. The 17th workout was the last workout. The 18th workout was omitted because of scheduling problems.

d. Subject's #10 and #14 pre-scores are based on workout #3. Both were recovering from injuries suffered at Spring football practice and did not engage in the program used for the 17th workout until the 3rd workout.

Table 3: A comparison of the 2nd and 16th workouts of the wholebody group subjects. (a)

	2nd Workout			16th Workout (c)			Net Change	
Subject (a)	Ave Wt (10 exercises)	Ave # of Reps	Duration (b) (in min)	Ave Wt. (10 exercises)	Ave # of Reps	Duration (in min)	Ave Wt. (in lbs)	Change (%)
1.	60.3	9.4	26	96.0	14.6	25	35.7	59.20
2.	75.5	14.4	31	114.0	12.1	23.5	38.5	50.99
3.	74.5	13.0	36	112.3	13.7	34	37.8	50.74
4.	68.5	11.9	31	103.0	12.3	21.5	34.5	50.36
5.	78.5	13.3	23	115.8	13.6	23	37.3	47.52
6.	72.0	11.9	30	105.5	12.4	24	33.5	46.53
7.	75.5	10.7	37	109.3	13.7	31	34.3	45.73
8.	72.5	13.3	35	103.0	12.2	23	30.5	42.07
9.	61.5	9.4	21	87.3	13.3	26	25.8	41.95
10.	66.5	13.3	26	94.0	13.2	22.5	27.5	41.35
11. (b)	77.5	21.5	44	109.0	12.2	22	31.5	40.65
12.	71.3	12.9	25	100.0	10.5	20	28.7	40.25
13.	80.3	11.8	N/A	112.0	13.1	N/A	31.7	39.48
14.	71.3	10.7	24	99.0	11.5	18	27.7	38.85
15.	76.5	16.9	33	106.0	15.5	28	29.5	38.56
16.	72.5	10.6	34	97.5	10.7	38	25.0	34.48
17.	82.3	10.9	23	110.3	10.6	19	28.0	34.02
18.	72.5	9.1	23.5	96.0	11.7	19	23.5	32.41
Mean=	72.7	12.5	27.92	103.9	12.6	23.19	31.2	43.06

a. The program used for the 2nd and 16th workouts differed from the one prescribed for the 1st and 17th days of training.

b. Subject #11's data for the 2nd workout is based on his 4th workout. He did not participate in the program used for the 16th workout until #4 because of training.

Over six weeks, the 18 wholebody subjects increased the amount of weight used in their first two workouts by an average of 58.54% and 43.06% respectively (note: comparisons were made of the 1st and 17th, 2nd and 16th workouts because of spatial reasons and because they were among the few times that an exact workout was repeated). The variance of change among the two "sets" of workouts (15.48%) can be attributed primarily to differences in the programs used for the first and second days of training. The program for the 1st and 17th workouts included one set each of the following exercises: squat, hip and back, leg curl, pullover, chins, dips, omni bench, torso arm, double chest, and decline press. In the 2nd and 16th workouts, a set of the leg extension, leg press, seated press, duo-poly curl, and duo-poly triceps was substituted for the squat, chins, dips, double chest, and decline press exercises.

Despite the significant changes produced, even the lowest level of improvement among subjects, certain factors likely prevented even greater change. During the initial four weeks of training for record, each subject participated in Spring football practice, and this would have resulted in an increased energy expenditure that minimized or restricted improvement for this project. Other demands included final academic exams that occurred during the final week of training. Moreover, some subjects missed several workouts (or trained at less than full capacity) because of minor injuries or illnesses (one member contracted the mumps but remained in the program nonetheless).

Tables 2 and 3 reveal another significant statistic: the subjects both increased their strength and decreased the time required to complete an identical workout. Despite a modest increase in the number of repetitions performed each workout, the duration of each session dropped over 9 minutes and 4.5 minutes respectively from the expended times for the initial two periods. By the 17^{th} workout, all subjects had to wear a device to add weight to their bodies for chins and dips. And considering that the entire 8 week program involved less than 8.5 hours of actual training per subject, the significant increase in strength and decreases in workout duration are even more remarkable.

In order to determine and measure the functional application of the training, three factors were administered to each member of both the wholebody group and the control group: 2-mile run (wind, stamina), 40-yard dash (speed), and vertical jump (leg power). These tests were chosen because of their seemingly universal acceptance by football coaches, as integral components of skills required to play football.

Table 4 indicates that the wholebody group improved their performance more than the control group. In fact, the differences were substantial. The wholebody's improvement was more than 4.32 times that achieved by members of the control group on the 2-mile run and 4.57 times greater on the vertical jump (consistent with the improvement made in leg strength). The wholebody group improved 1.89 times the rate of the control group for the 40-yard dash. Less improvement was made in the 40-yard dash for the reason that prior to this project's training both groups used the 40-yard dash as part of their conditioning program to prepare for Spring football practice, but once Project Total Conditioning and Spring practice began, the 40-yard dash was phased out.

Table 4. A comparison of wholebody group vs. control group performance on 3 functional measures.

TWO MILE RUN (a)

	Pre-Training (in min)	Post-Training (in min)	Mean Difference (in sec)	Improvement (%)
Wholebody Group (N = 19)	13:18	11:50	88	11.02
Control Group (N = 15)	13:04	12:44	20	2.55

FORTY YARD DASH (b)

	Pre-Training (in min)	Post-Training (in min)	Mean Difference (in sec)	Improvement (%)
Wholebody Group (N = 19)	5.1467	5.0933	0.0534	1.04
Control Group (N = 15)	4.7933	4.7667	0.0266	0.55

VERTICAL JUMP (c)

	Pre-Training (in inches)	Post-Training (in inches)	Mean Difference (in inches)	Improvement (%)
Wholebody Group (N = 19)	22.600	24.067	1.467	6.49
Control Group (N = 15)	21.692	22.000	0.308	1.42

a. Run on a tartan, indoor track.

b. Best of one trial, run in tennis shoes, administered in the gymnasium.

c. Best of three trials, one hand reach.

Neck Strengthening

Neck strengthening was one of the focuses of this project since the neck area ranks as one of the most common and serious injuries a person could sustain in sports. However, most strength and conditioning programs provide minimum attention to the neck, and what commonly is available include either callisthenic-type exercises such as bridging, using a training buddy (one individual pushes against the resistance provided by someone else), or external paraphernalia such as harness straps that accommodate free weights. These methods generally are awkward and do not allow for proper movement, or produce less than desired results.

In Project Total Conditioning, an effort was made to eliminate the first problem, which served to eliminate the second. Three machines were used to work the neck in proper form and relative to the neck's basic functions. Members of the inter-collegiate football team were divided into three groups, the first of which consisted of the 19 wholebody subjects discussed previously, who included neck training in two of their three weekly workouts. The second group was the 'neck-only' group, with 16 individuals having limited their training to muscles of the neck and shoulders, three times per week. The third group comprised of 14 individuals who served as the 'control' group, who did not participate in the training conducted in the project. Any exercises these individuals performed were done on their own or under the auspices of the USMA football staff.

One basic program was used for all neck training workouts, which required each subject to perform one set of six exercises: shoulder shrug, neck rotation (rotary neck), and the exercises done on the 4-way neck machine (flexion, extension, and lateral flexion to both right and left). When 12 repetitions were possible (six each direction on the rotary neck), the resistance was increased to the next increment. Initially it took about 8 minutes for each participant to complete a 'neck' workout, and eventually 7 minutes thereafter.

The results from the first two weeks were ignored, to account for the 'learning effect.' Training-for-record started at the sixth workout, with Table 5 providing the data between group differences from six weeks of training.

The subjects in both the wholebody and the neck-only groups increased relative neck strength (91.92% and 56.72% respectively) at a greater level than did the control group (27.84%). It should be noted that the wholebody group did receive closer supervision and encouragement to train hard, which possibly had an influence on outcomes; the neck-only group was provided periodic supervision only. Nonetheless, the changes for either group are more substantial when it is considered that the improvements were made in about two hours of total training time.

Table 5. A comparison of the results of the neck strengthening program. (a)

TENSIOMETER STRENGTH (b)

	Pre-Training	Post-Training	Mean Difference	Improvement (%)
Wholebody Group (N = 18)	586.28	1,125.16	538.88	91.92
Neck-Only Group (N = 16	571.06	894.94	323.88	56.72
Control Group (N = 16)	620.50	793.25	172.75	27.84

NECK CIRCUMFERENCE (c)

	Pre-Training (in inches)	Post-Training (in inches)	Mean Difference (in inches)	Improvement (%)
Wholebody Group (N = 19)	16.38	16.82	+ 0.44	2.67
Neck-Only Group (N = 16)	16.28	17.03	+ 0.75	4.61
Control Group (N = 14)	16.47	16.62	+ 0.15	0.91

a. The pre- and post-test data on the average amount lifted and number of repetitions performed is not presented because the neck-only group subjects trained in a semi-supervised environment. As such, their recorded number of properly performed repetitions could, in some instances, be inaccurate.

b. The totals reflect the sum of four tensiometer measurements: one each for extension, flexion, lateral flexion (left) and lateral flexion (right). The scores on one of the wholebody subjects were omitted because he was sick on the day the testing was conducted.

c. No pre-training measurement was taken for two control group subjects.

Cardiovascular Fitness

Cardiovascular fitness is an important aspect of a person's level of overall physical fitness and the capacity to sustain athletic performance. Traditionally, physicians and fitness experts have suggested that strength training cannot increase a person's capacity to meet the transport (oxygen in and CO_2 out) requirements of strenuous exercise, to improve 'cardiovascular (CV) fitness.' Nonetheless, it has been agreed upon that in order to improve CV fitness, heart rate should be sufficiently high (about 145-150 bpm); this rate should be sustained for a minimum of 10-12 minutes, and such exercise should be conducted 3-4 times per week (although research is equivocal on the exact number of times).

In conventional strength training programs, although heart rate can reach high levels, it is not sustained for long, as trainees tend to rest between sets of activity. Conversely, in Project Total Conditioning there was an attempt made to train the wholebody subjects in such a manner that overall CV fitness would occur… by limiting the rest between exercises to a few seconds and by exercising with a high degree of intensity of effort.

To determine the effects of this training, several tests were administered (pre- and post-training) to both the wholebody and the control group members. Differences on the initial test date were determined by a T-test for each variable. If there were no initial significant differences, then the T-test was applied to the post-training data; but if there were significant differences, then analysis of covariance was used to determine the relative degree of any change that occurred between the two groups.

Three different states of the CV function were examined: 1) CV capacity at rest; 2) responses to sub-maximal work; and 3) responses to maximal work. The tests for the resting state consisted of measuring each person's heart rate (HR), systolic and diastolic blood pressure (SBP and DBP), and systolic tension time index (an accepted measure of coronary circulation that is calculated by multiplying HR x SBP = STTI).

Effects on the sub-maximal state were determined by having each subject perform on a Body-Guard model 990 bicycle ergometer (a basic research instrument whereby a person pedals against a predetermined load that can be adjusted when necessary by the experimenter). The sub-maximal tests had each subject perform a continuous, progressive ergometer ride with increasing work loads (360 kpm/min increase) every two minutes until the subject could no longer sustain the rate of 60 rpm or wanted to stop. This was followed by two minutes at the initial light load (360 kpm/min), then three minutes of rest. At each condition, the HR, SBP, DBP, STTI, and a subjective exertion rating by the subject were obtained. Use of a continuous EKG was used to obtain cardiac feedback while on the ergometer. The maximal state was determined by means of two measures: total riding time and a 2-mile run performance. Except for the 2-mile run performance, all CV testing was conducted by outside consultants (including those from the Cooper Institute), individuals who were not informed which subject was part of which group to increase objectivity and legitimacy.

The result of the testing were conclusive, in that NONE of the 60 indices purporting to evaluate the effects of the training on CV function was superior in the control group better than the wholebody group, on the final testing period or on the change from initial to final. The following significant differences (.05 level*) were caused by the training afforded by the wholebody group: Lower HR at 360, 1080, 1260, 1620, and 1800 kpm/min; lower STTI at 360, and RPE at 1260; a higher amount of work necessary before the subject achieved a HR of 170; a longer ride time; and a lower time required to run 2 miles. These calculations mean more efficient work (lower HR) at light, moderate and near maximal levels, and the wholebody group could do more total work and more work before reaching a HR of 170. These results should make the importance of such training for athletes evident.

Flexibility

Flexibility refers to the degree to which a joint is free to move throughout its normal range of motion, determined by the musculature surrounding a specific joint. Even to this day there is a 'fear' that flexibility will reduce as a result of strength training, and that muscle hypertrophy will result in reduced flexibility. However, if strength training is applied properly, and with the right tools, flexibility can be enhanced.

In the above regard, development of a proper strength training program should take into consideration the following factors: 1) for each exercise, a muscle should be stretched through a full range of motion; and 2) both agonist and antagonist (opposing muscles on either side of a joint) should experience equal attention.

In Project Total Conditioning, steps were taken to comply with these fundamentals, and by design the Nautilus machines required subjects to stretch fully and perform exercise through a full range of motion, as well as provide sufficient activity for each agonist-antagonist pair among the major muscle groups.

Four measures of flexibility were evaluated in this project: trunk extension, trunk flexion, shoulder extension, and shoulder flexion. Subjects in the wholebody and control groups were tested on a pre- and post-training basis, and the relative degree of change on the four aspects over the six-week period indicated the results.

Table 6 illustrates that the training produced significant changes in flexibility, and that the wholebody group achieved far superior improvements than the control group (10.92% vs 0.85% respectively as an average gain). Shoulder flexion data is not provided as the data was obtained through the coordinated use of synchronized photography and a goniometer after the initial report's development, and I am unaware of what was found.

* Researchers commonly use .05 as the level of significance, to suggest (in this instance) that the differences can be accepted with 95% degree of certainty as having occurred as a result of the special training.

Table 6. A comparison of the effects of training on flexibility.

TRUNK EXTENSION

	Pre-Training (in inches)	Post-Training (in inches)	Mean Difference (in inches)	Improvement (%)
Wholebody Group (N = 18)	46.33	53.55	7.22	15.58
Control Group (N = 16)	47.44	48.06	0.62	1.31

SHOULDER FLEXION

	Pre-Training (in inches)	Post-Training (in inches)	Mean Difference (in inches)	Improvement (%)
Wholebody Group (N = 15)	47.33	52.83	5.50	11.62
Control Group (N = 15) (a)	50.75	51.25	0.50	0.99

TRUNK FLEXION

	Pre-Training (in inches)	Post-Training (in inches)	Mean Difference (in inches)	Improvement (%)
Wholebody Group (N = 18)	47.94	50.61	2.67	5.57
Control Group (N = 16) (a)	50.50	50.63	0.13	0.26

a. One control group subject was omitted because of a shoulder injury.

Body Composition

Two types of body fat calculations were obtained for Project Total Conditioning, as determined by a machine known as the Whole Body Counter and skin-fold measurements. Prior to the first workout of training-for-record and at the conclusion of the six-week study, the wholebody group was flown to Rochester, NY, at the University of Rochester Medical School (it was cost prohibitive to fly the control group). Body composition was measured with the Whole Body Counter by measuring the radiation given off by the potassium K in the body, with the results shown in Table 7.

It was discovered that only eight of the nineteen subjects lowered the overall level of body fat, and the group as a whole actually increased body fat slightly. These calculations were not as expected and contradicted the visual interpolation of pre- and post-training photographs of the subjects in their gym shorts. However, the Rochester personnel reported that the machine had an error rate of 4% and that pre- and post-testing was conducted by two different sets of individuals, both of which factors could account for the discrepancy.

Further, two sets of skin-fold measurements were obtained, the first by the Rochester personnel and the second by the USMA personnel. However, it is known that skin-folds are unreliable for indicating body fat composition, and this was confirmed when Rochester showed a slight increase on the skin-fold tests, whereas the USMA calculations showed a substantial decrease for both groups. On the USMA measurements, the wholebody group improved slightly better (19.4%) than did the control group (18.5%).

Concurrent Studies

Two secondary studies also were conducted, lasting only four weeks. In the first study 24 rugby players were examined to determine the effects on overall neck strength of a twice-weekly vs a three-times-weekly workout program (the content of the program was the same as explained previously). The two-times per week group produced a slightly greater increase in neck strength (41.6%) as opposed to the three-times weekly group (39.8%), thus suggesting that there exists a point of diminishing returns when attempting to achieve the greatest response with the least amount of exercise.

In the second study, 22 USMA volleyball members were tested for the overall effect on their vertical jumping ability using the Nautilus Super Hip and Back Machine vs one that uses the Nautilus DUOsymmetric POLYcontractile Hip and Back Machine (wherein the subjects lowered the weight with one leg while being forced to keep the other leg in a contracted position). Both programs involved one set, three times weekly, for a total expended time of less than 60 seconds per workout. The results are shown in Table 9.

Although both programs increased the average vertical jump, the DUO-POLY workout produced the greatest increase or change. Because little research or investigation has been made into the effects of DUO-POLY contractions of strength training results, this finding encourages further research.

Table 7. A comparison of the effects of training on the wholebody subjects' level of lean muscle mass and body fat.

	Lean Body Mass (in lbs)	Body Fat (in lbs)	Fat (%)
Pre-Training (N = 19)	182.34	26.48	12.4
Post-Training (N = 19)	180.48	27.50	13.0
Mean Difference	- 1.86	+ 1.02	0.6

Table 8. Fat caliper measurements for subjects involved in Project Total Conditioning. (a)

	Rochester (b)			USMA (c)		
	Pre-Training	Post-Training	Mean Difference	Pre-Training	Post-Training	Mean Difference
Wholebody Group (N = 19)	9.97	10.42	+0.45	6.25	5.04	- 1.21
Control Group (N = 10)	N/A	N/A	N/A	6.48	5.31	- 1.17

a. All measurements are in millimeters.

b. The Rochester data is based on an average of five measurements: biceps, subcostal, umbilical, iliac, and subscapular.

c. The USMA data is based on an average of several areas: chest, axilla, triceps, subscapular, abdomen, suprailliac, and frontal thigh.

Table 9. A comparison of the effects of a program using a Super Hip and Back Machine vs one using a DUOsymmetric POLYcontractile Hip and Back Machine.

	Pre-Training (in inches)	Post-Training (in inches)	Mean Difference (in inches)	Improvement (%)
Regular Hip and Back	22.222	22.722	0.50	2.25
DUO-POLY Hip and Back	21.45	22.86	1.41	6.57

Summary

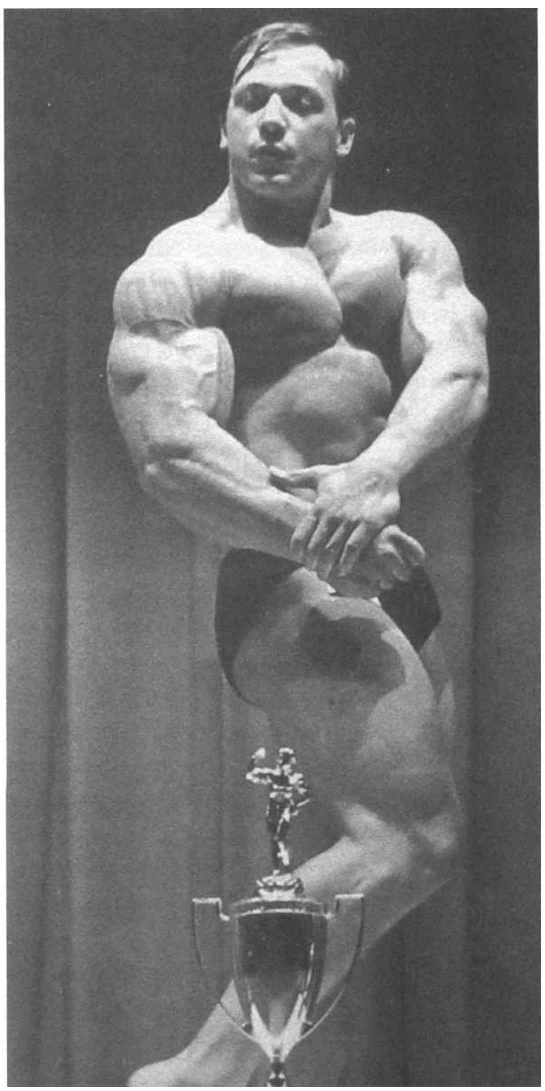
Primarily, this project demonstrated that a properly developed strength training program can produce positive change in less than six weeks, even with experienced trainees. The program does not have to be long, but should be brief, intense and infrequent. In this instance, high-intensity training increased the average overall strength of each subject by more than 58%. Neck strength also increased significantly among the wholebody and neck-only groups by an average of 91.9% and 56.7% respectively.

Contrary to what many people believe, strength training also significantly improves cardiovascular condition, accomplished by maintaining the intensity of the workouts at a high level of effort while limiting rests between sets, and doing so resulted in improvement on each of 60 separate measures of cardiovascular fitness. Moreover, the data suggests that some of these cardiovascular benefits cannot be achieved by any other type of training.

Lastly, the subjects increased their level of flexibility on average by 10% on the three evaluative items. Again, popular myth suggests that weight training will make a person less flexible, more stiff, and even ‘muscle bound.’

Competitive Bodybuilders

Certainly the examples of bodybuilders in this section can be challenged, in that they have superior genetics, took anabolic steroids, and that there are other bodybuilders who are as well developed and who have not used high-intensity training to achieve a championship build. Although true, we need to look objectively at the relativity of such a comparison, in that the individuals presented in this section have developed their bodies in a fraction of the time and with far less volume and frequency than other competitive bodybuilders. In other words, it is possible to optimize muscular strength and size without spending countless hours in the gym. Also, consider the dramatic changes that Casey Viator made in 28 days, in The Colorado Experiment discussed earlier in this chapter, and then compare that to the 5-days-per-week for 2 hours each time that Arnold Schwarzenegger undertook, for several months prior to the 1980 Mr. Olympia (and although Arnold won that contest with much political controversy, he was no where near his optimum form and muscular size).

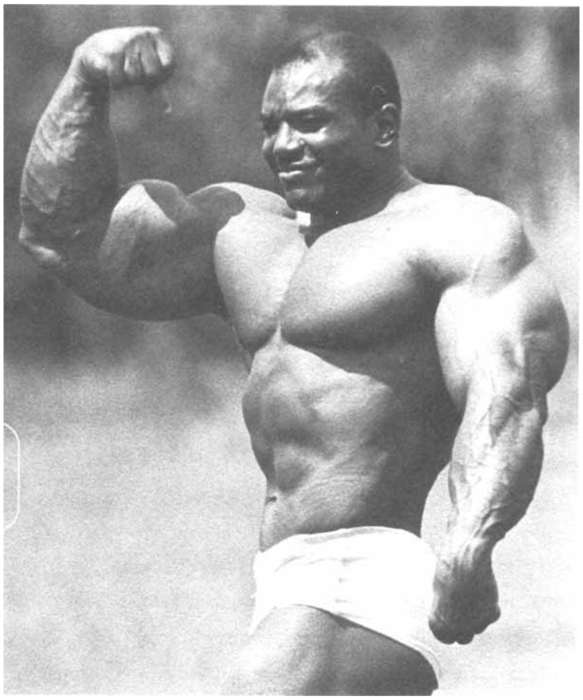


Casey Viator

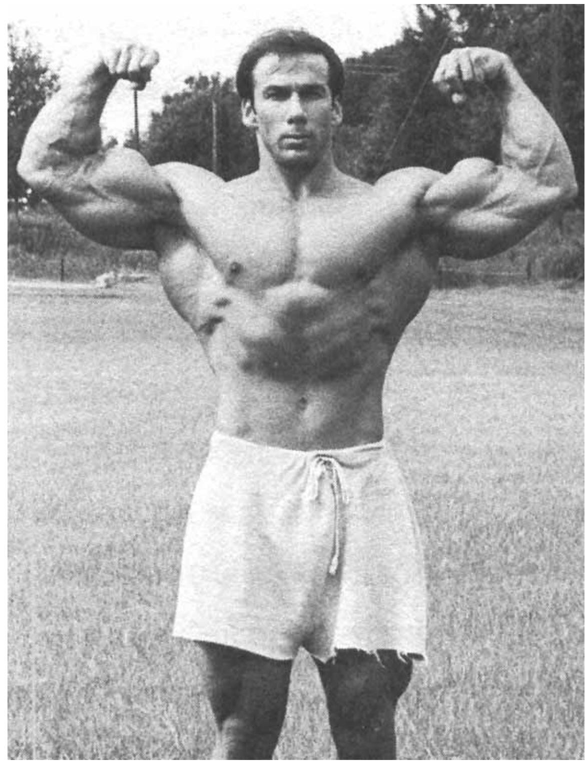
In this photo, Casey won the Mr. America at age 19 (along with all best body parts except abdominals), the youngest in history to win the contest. His method of training was high-intensity, as supervised by Arthur Jones. Two days prior to the Mr. America, Ellington Darden, Dr. Elliott Plese, and Kim Wood (University of Wisconsin strength and conditioning coach) witnessed the following workout (with no rest, unless otherwise indicated):

1. Universal leg press (750 lbs x 20 repetitions)
2. Universal leg extension (225 lbs x 20 repetitions)
3. Full barbell squat (502 lbs x 13 repetitions), followed by a 2-minute break.
4. Universal leg curl (175 lbs x 12 repetitions)
5. Single leg calf raise (40 lbs x 15 each leg)
6. Nautilus Pullover (290 lbs x 11 repetitions)
7. Nautilus behind-neck lat-isolation exercise (200 lbs x 10 repetitions)
8. Nautilus row (200 lbs x 10 repetitions)
9. Nautilus behind-neck pulldown (210 lbs x 10 repetitions), followed by 2 minute rest
10. Dumbbell shoulder lateral raise (40 lbs dumbbells x 9 repetitions)
11. Barbell behind-neck shoulder press (185 lbs x 10 repetitions)
12. Nautilus biceps curl (110 lbs x 8 repetitions)
13. Chin-up (bodyweight x 12 repetitions), followed by 2 minutes rest
14. Nautilus triceps ext (125 lbs x 9 repetitions)
15. Parallel dip (bodyweight x 22 repetitions)

Total time: 27 minutes, 40 seconds with rests.

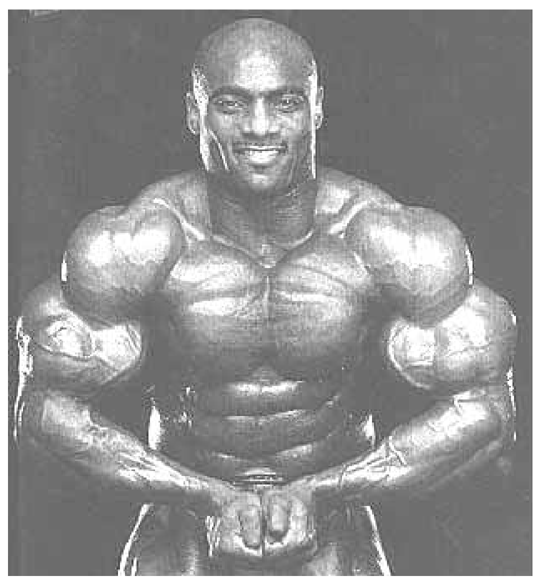


Sergio Oliva, 3-time Mr. Olympia, achieved his most muscular condition with Arthur Jones, while performing full-body, high-intensity exercise (as shown in this photo). Sergio is the only man ever to have a muscular arm that measured wider than his head was high.

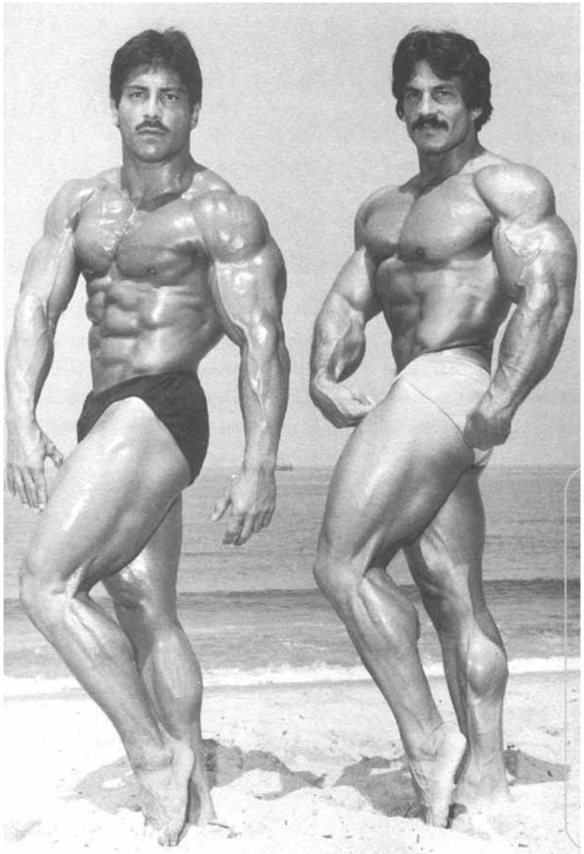


Boyer Coe, Mr. Universe (circa 1970)

Dorian Yates, 6-time Mr. Olympia

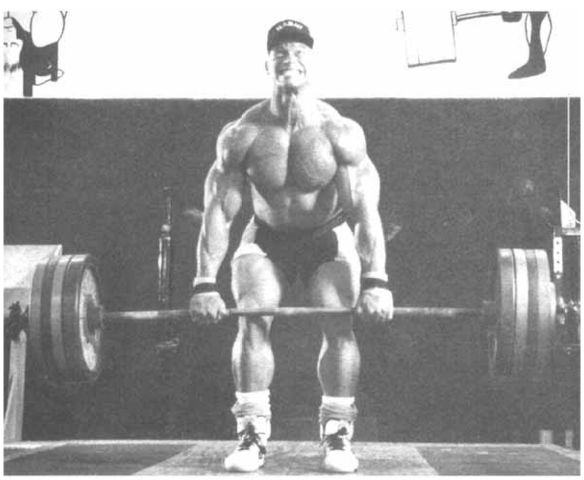


Ernie Taylor, IFBB professional bodybuilder and Yates pupil



Ray and Mike Mentzer,
both Mr. Universe title winners

Scott Wilson, Mr. International



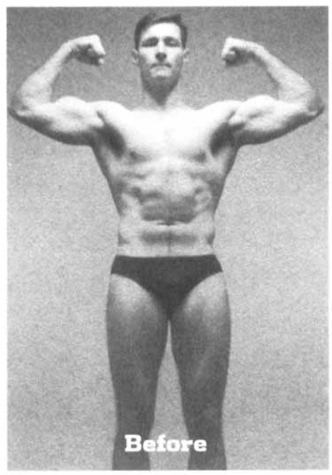
Keith Whitley

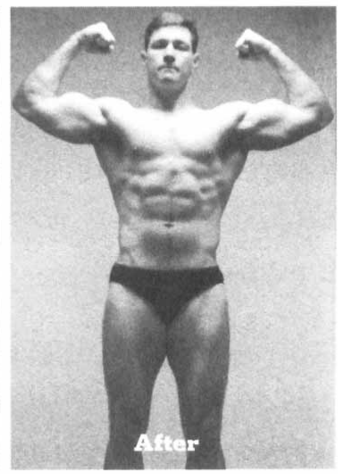
Andy McCutcheon, the famous Bowflex model who always is in shape

Fitness Enthusiasts

David Hudlow

David Hudlow is an example of a non-drug using individual with good genetics, who undertook an intensive strength training and physique transformation program under the supervision of Ellington Darden in 1990. Hudlow's direction was different than most bodybuilders, in that he first leaned down over the course of 66 days before attempting to gain weight. The result was a loss of 50 pounds of fat and 9.25" off his midsection, with an overall decrease of 28.4 to 5 percent body fat. He also built 4.75 pounds of muscle during that time. See the before and after photo set to the left.





Hudlow's next objective was to increase muscle mass. He trained with Routine A on Monday and Friday of the first week and on Wednesday of the second week, and Routine B on Wednesday of the first week and Monday and Friday of the second week, etc.

Routine A	Routine B
1. Stiff-legged deadlift with barbell	1. Barbell squat
2. Leg-extension machine	2. Standing-calf raise machine
3. Leg-curl machine	3. Dumbbell lateral raise
4. Straight-arm dumbbell pullover	4. Chin-up (negative only)
5. Biceps curl with barbell	5. Dip (negative only)
6. Triceps pushdown with cable machine	6. Shoulder shrug with barbell
7. Reverse wrist curl with barbell	7. Abdominal crunch

The changes he made in only 14 days of intense exercise, with a normal mixed diet and super water hydration/creatine loading is illustrated in the second photo set to the right and above:

Measurement	January 11	January 25	Increase
Body Weight	173.5 lb	192 lb	18.5 lb
Neck	15.5 in	16.25 in	.75 in
Upper Arm	15.5 in	16.9 in	.75 in
Chest	43 in	46 in	3 in
Thigh	22.2 in	23.75 in	1.55 in
Calf	14.2 in	15.2 in	1 in

Clarence Bass
Age = 60
Years Training = 45

Accomplishments: winner of his height class Mr. America Past 40 and Mr. U.S.A Past 40; Best Abdominals, Best Legs, Most Muscular Mr. U.S.A. Past 40. Well known for ability to reduce and maintain low levels of body fat (personal best 2.4%).

Training protocol: Clarence's current routine involves single sets to "near" failure of 13 exercises per workout performed only once a week. Clarence understands the importance of training with sufficient intensity to elicit the growth response and has, over the years acquired the ability to train with white-hot intensity while maintaining perfect exercise form. Clarence notes that he usually trains one repetition short of failure, and always strives to increase the resistance on a workout-to-workout basis. The fact that Clarence continues to get stronger suggests that his 'one repetition short of failure' is sufficient for him to set the growth mechanism into motion. Of course, given his experience and adherence to perfect exercise form, his sets of one repetition short of failure are likely far more intense than most trainees who actually go to failure (and light years away from those trainees who terminate a set when the weight feels heavy or when they have reached an allotted repetition count).

There is considerable overlap in the exercises Clarence employs (e.g., pulldowns, biceps curls [see routine below]) but his consistent and considerable progress over the years implies that he has better than average exercise tolerance/recovery ability. Clarence periodically alters his repetition/resistance scheme (i.e., 20 rep sets, 12 rep sets, 8 rep sets) to avoid "staleness" and to keep his motivation high by creating new challenges for himself.

As Clarence ages he systematically and precisely alters the frequency of his weight training to maximize its effectiveness. This implies that Clarence wants each and every workout to be a productive and progressive venture. He simply will not workout unless absolutely convinced that he has fully recovered from the previous session. Interestingly, Clarence also applies the high intensity training protocol to his cardiovascular training.

Brief, brutally hard aerobic exercise sessions performed once a week (on a different day from his weight training) have kept Clarence at the peak of fitness and health. His periodic preventive health care visits to the renowned Cooper Clinic in Dallas Texas have confirmed the success and effectiveness of his rationally based training protocols. Specifically, Clarence recently scored in the top 1% for men his age in strength and cardiovascular fitness. He also displayed bone density levels above those expected of even 20 year olds. Although there is little doubt that Clarence Bass is genetically endowed with respect to gaining muscle mass, losing body fat, and cardiovascular fitness, his approach is based on sound principles applied consistently over several decades.

Clarence Bass, aged 40

Clarence Bass, aged 60

Routine A	Routine B
Power Snatch	Power Clean
Squat	Deadlift
Standing Calf Raise	Calf Raise (w/ leg press machine)
Two Dumbbell Row	Nautilus Pullover
Front Lat Pulldown	Rear Lat Pulldown
Incline Barbell Press	Bench Press
Cable Crossover (kneeling)	Cable Crossover (standing)
Dumbbell Shoulder Press	Seated Machine Press
Barbell Curl	Preacher Pulley Curl
Triceps Pushdown	Dumbbell Triceps Extension
Crunch (feet elevated)	Crunch (feet flat)
Hanging Leg Raise	Hip Curl
Dumbbell Side Bend	Seated Side Bend

For more information on Clarence's training, consult his web site: http://www.cbass.com

Richard Winett, Ph.D.
Age = 53
Years training = 40

Accomplishments: Lifetime drug-free bodybuilder, publisher of *Master Trainer*, a newsletter devoted to the dissemination of scientifically-based information on bodybuilding, health and fitness. Dr. Winett also writes a monthly column (High Intensity Forum) for *Ironman magazine*.

Training Protocol: Dr. Winett is a fine example of a bodybuilder who has refined his training over the years from an essentially high-volume, high-frequency (i.e., 100 sets per week, three-days-on, one-day-off [also 3 hours/week of cardiovascular training]) regimen to a low-volume, relatively low frequency (i.e., 20 sets per week, one-day-on, one-day-off [also 48 minutes/week of cardiovascular training]) routine. Dr. Winett characterizes himself as someone with a very high tolerance for high intensity exercise. The impressive results he derived (e.g., over two-times bodyweight for high repetitions in the squat and deadlift) from the high-volume, high-frequency protocol supports his contention. As Dr. Winett notes, *"Except for being tired all the time (not a trivial problem), I actually did quite well on this regimen ... I'm probably not the best example of someone who suddenly bloomed with high-intensity approaches. Rather, my case probably shows how much less exercise I could have done when I was younger and at least achieved the same results – maybe somewhat better."*

Dr. Winett implements slow and controlled movement. He notes, *"I think what I am doing now with the slower repetition speeds is probably the best training I've ever done because the injury factor and joint inflammation are virtually nonexistent. It's also the most intense form of training I've ever done. That's because when you move at a slow speed, there's very little momentum and your muscles are completely under tension for the duration of the set. With the quicker reps I used to do, there's a constant loading and unloading of tension so it's really a lot less intense."*

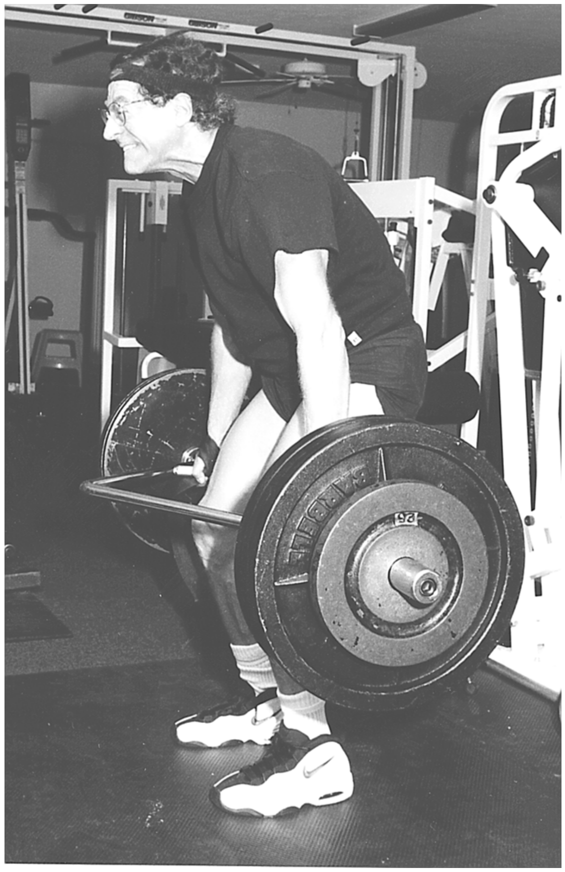
Dr. Winett estimates that the repetition cadence for his former routine was 1.5 seconds to raise the resistance and 1.5 seconds to lower it. Dr. Winett also noted that each set was taken to failure.

When the two protocols are compared (i.e., 20 sets vs. 9 sets), his current protocol represents a 55% reduction in volume! The fact that Dr. Winett reports consistent progress while using both routines, despite the volume of the routines (especially the former), and that the exercises in both routines show significant overlap (e.g., performing squats and leg presses in the same workout), is strong evidence that he possesses better than average exercise tolerance/recovery ability. Given the impressive strength/physique he has developed training in this manner, it is likely that if he decided to reduce the volume and frequency of his training even further (while keeping the intensity as high as possible) he may improve even more.

In any event, Dr. Winett notes that in the late 1980's and early 1990's his total training time per week was about 7½ hours (4½ weight training and 3 cardiovascular training). His current protocol finds him training about 2 hours a week (75 minutes weight training 45-48 minutes cardiovascular training). Dr. Winett is also an avid walker (about 20 miles per week). He does this for recreation and to burn a few extra calories. Summarizing the contrast between his high and lower volume weight training protocols, Dr. Winett said, *"with the high volume, more frequent training, I was often exhausted and many times didn't successfully make all the appropriate lifts . . . so there were some real physical and psychological costs to the approach. Now you're looking at 7½ hours per week versus about 2 hours per week. Unless there was a large difference in the outcome between the two, which there aren't, on the sheer basis of cost-effectiveness, the high-intensity approach wins hands down."*

Below is a comparison of Dr. Winett's former and current leg/lower back workouts.

Former Leg/Lower Back Workout	Current Leg/Lower Back Workout
Squat: 2 sets	Squat: 1 set
Leg Press: 2 sets	Led extension: 1 set
Leg Extension: 2 sets	Leg Press: 1 set
Stiff Leg Deadlift: 2 sets	Stiff Leg Deadlift: 1 set
Leg Curl: 3 sets	Nautilus Lower Back: 1 set
Standing Calf Raise: 2 sets	Leg Curl: 1 set
Leg Press Calf Raise: 2 sets	Standing Calf Raise: 1 set
Seated Calf Raise: 2 sets	Seated Calf Raise: 1 set
Dumbbell Side Bend: 2 sets	Dumbbell Side Bend: 1 set
Twisting Cable Crunch: 1 set	



For more information on Dr. Winett and his *Master Trainer* Newsletter, consult his internet site: http://ageless-athletes.com

Paula Schaffer

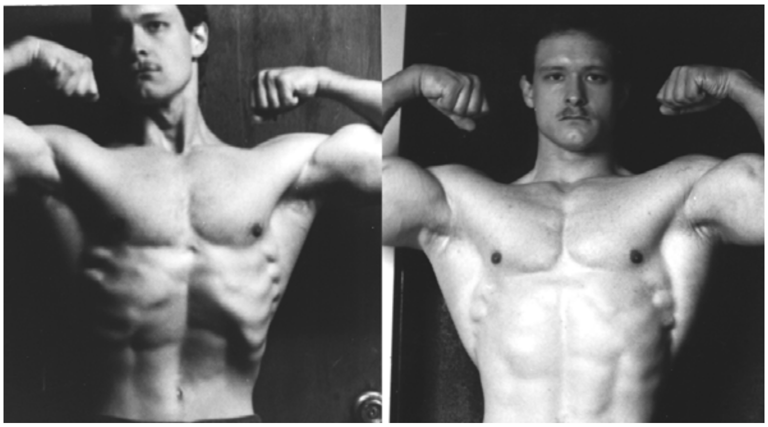
Paula is 5' 4", 114 pounds year round, even when competing. At 43 years of age, she holds several bodybuilding titles, including 1st place Vancouver Natural 1996, 1st place Bend Summer Classic, 2nd place Vancouver Natural 1997. At Paula's last competition she measured 4.5-5.4% bodyfat via hydrostatic weighing.

She currently strength trains 1-2 times per week, although she's leaning toward training only 1 time weekly. Her sessions include a maximum of 8 exercises, lasting less than 30 minutes of total gym time.

Workout #1	**Weight**	**Reps**	**Negatives**
Hack Squat (warm up)	0 lbs	12	
Hammer Strength Leg Press	320 lbs	13+	3-5
Hack Squat (10 sec. pos/neg)	20 lbs	8	
Alternate each week:			
One legged calf raise, or	50 lbs	12+	3-4
Nautilus leg curl	110 lbs	10-12	3-5
Rotator Cuff Warm Up			
Pull ups		11-13	
Nautilus 10 Degree Chest	100 lbs	8-10	3-4
Hammer Wide Chest	80 lbs (per side)	8-10	
Dumbbell Biceps Curl	25 lbs	8+	
Dumbbell Shrugs	100 lbs	10+	
Workout #2			
Same as #1 for legs including...			
Hammer Strength Wide Chest	80 lbs	8-10	3-5
Pull Ups	Body	11-13	
Stiff Arm Lever	40 lbs	12-14	1-2
Hammer Over Head Press	35 lbs	7-8	2-3
Cable Row	90 lbs	9-10	2-3

Brian D. Johnston

"I've made tremendous progress since I converted my program from the typical high volume training to something that is more intense, yet greatly reduced in volume and frequency. The accompanying photos below compares my condition of 162 pounds, after ten years of high volume (5-6 days per week, 1-1.5 hours daily), followed by only one year of very intense exercise for 2 sessions per week for less than 30 minutes each, at a bodyweight of 186 pounds.



"I produced as good of progress in a one year span, while I utilized a more rational training protocol, than I did in the previous 10 years. If one considers that most progress should occur within the first 1-2 years, it is a clear indication of the irrationality that a blind, voluminous approach had in the efficacy of my progress, and my current aversion for the physical culture magazines that initially distorted my perception of reality."

Below are photos of Brian Johnston at age 40 (2005), and while maintaining a high-intensity protocol on a split routine (upper body on Wednesday and lower body with abs/rotator cuffs/forearms/neck on Saturday).

Brian is available for consultations, and he can be reached at: info@ExerciseCertification.com

Sports Teams & HIT

The following list was compiled by Matt Brzycki, Fitness Coordinator of Princeton University, for a 1999 article in *Exercise Protocol* magazine:

1996-97: Nine NFL teams trained HIT, including the Arizona Cardinals, Carolina Panthers, Cincinnati Bengals, Minnesota Vikings, Philadelphia Eagles, Pittsburgh Steelers, San Diego Chargers, Tampa Bay Buccaneers and Washington Redskins. During the regular season, these nine teams had a record of 59-45 against teams that not train HIT, which is 14 games over .500 and a winning percentage of .567. In other words, teams whose players did not train HIT were 14 games under .500 and a winning percentage of .433. Four teams that trained HIT made the playoffs (Pittsburgh, Carolina, Philadelphia and Minnesota).

1997-98: Nine NFL teams trained HIT, including the Arizona Cardinals, Carolina Panthers, Cincinnati Bengals, Minnesota Vikings, New York Giants, Philadelphia Eagles, Pittsburgh Steelers, Tampa Bay Buccaneers and Washington Redskins. During the regular season, these nine teams had a record of 45-42-1 against teams that did not train HIT, which is 3 games over .500 and a winning percentage of .517. In other words, teams that did not train HIT were 3 games under .500 and a winning percentage of .483. Four teams that trained HIT made the playoffs (Pittsburgh, Tampa Bay, New York Giants and Minnesota).

Since 1982: Football players for the Washington Redskins have trained HIT since 1982. In those 16 years, their regular season record was 149-101-1 (a winning percentage of .596) and their post-season record is 16-5 (a remarkable winning percentage of .762) including 3 Super Bowl championships (in 1982, 1987 and 1991) and one second-place finish (1983). Their overall record in those 16 seasons was 165-106-1 (a winning percentage of .609). How many teams have even gone to the Super Bowl three times since 1982 let alone won it three times? Also, four other teams who trained HIT have made it to the Super Bowl: Cincinnati (twice), San Diego, and Pittsburgh.

College Football: At the Division I-A level in the 1996-97 season, five football programs that included HIT went to bowl games: Penn State, Michigan State, the University of Michigan, the United States Military Academy (Army) and Stanford University. In the 1997-98 season, five football programs that included HIT went to bowl games: Penn State, Michigan State, the University of Michigan, Stanford University and the University of Cincinnati. In other words, more than 60 Division I-A teams that did not include HIT did not play in a bowl game during each of those two seasons.

The Penn State football team has won two national championships since 1982 (1982 and 1986). How many college football teams have won more than two national championships since 1982? Answer: not many. Penn State was also considered to be at least the second-best team in the country in 1994 (with a 12-0 record) and the third-best in the country on two other occasions (1981 and 1985) – all while training HIT.

1997: The University of Michigan football team (2+ decades of HIT) was voted a share of the national title. Michigan finished second in 1985 and has had two Heisman Trophy winners in the 1990s: Desmond Howard in 1991 and Charles Woodson in 1998. At the Division I-AA level in the 1997-98 season, Villanova University trained HIT and finished the regular season ranked number one in the United States with an 11-0 record. At the end of the post-season, Villanova was ranked fifth in the country with a record of 12-1.

Individual accomplishments of football players who trained HIT: Besides Michigan's two recent Heisman winners, the name Anthony Munoz comes to mind. He trained HIT for more than a decade with the Cincinnati Bengals and is regarded by many as the greatest offensive lineman in the history of football.

College Basketball: The University of Kentucky players went to three consecutive Final Fours from 1996-98. They won the title in 1996, finished second in 1997 and won the title again in 1998. They also went to the Final Four in 1993. The University of Michigan players won the NCAA title in 1989. They also finished second in 1992 and 1993. The University of Cincinnati made the Final Four in 1992.

In 1998, at least nine teams that trained HIT made the NCAA Tournament and two of those teams went to the Final Four: the University of Kentucky and Stanford University. The United States Women's Basketball Team trained HIT on its way to the gold medal in the 1996 Olympics.

Ice Hockey: The Pittsburgh Penguins won two Stanley Cups in 1990-91 and 1991-92. In men's ice hockey, the University of Michigan won the 1997-98 NCAA Championship.

Wrestling: In 1988, Mark Coleman won the NCAA wrestling championship at 190 pounds for Ohio State. He won the tenth Ultimate Fighting Championship (UFC), at 6'1", 250-pounds: "I do every set to failure. It just doesn't make sense if you don't go to failure. It's a wasted set otherwise."

Baseball: In 1996, the University of Miami baseball team trained HIT yet made it all the way to finals of the College World Series, finishing second to Louisiana State University.

Volleyball: In 1997, two teams that trained HIT were in the finals of the NCAA Women's Volleyball Championships: Stanford and Penn State. Stanford won the championship that year – its second national title in a row. Their records for their two championship seasons were 30-2 and 33-2. The men's volleyball team at Stanford also won an NCAA championship in 1997, finishing the season with a record of 27-3.

Tennis: In 1996-97, both the men's and women's NCAA Championship were won by Stanford – it was the women's third straight national title. In 1997-98, Stanford repeated as the men's NCAA champion in tennis.

Swimming: In 1997-98, both the men's and women's NCAA Championship were won by Stanford.

Current Professional Teams & HIT

NFL*
Arizona Cardinals
Baltimore Ravens
Carolina Panthers
Cincinnati Bengals
Denver Broncos
Detroit Lions
Houston Texans
Indianapolis Colts
Jacksonville Jaguars
Minnesota Vikings
NY Giants
Philadelphia Eagles
Pittsburgh Steelers
San Francisco 49ers
Washington Redskins**

MLB
Detroit Tigers
San Diego Padres

NHL
Pittsburgh Penguins

NBA
Boston Celtics
Toronto Raptors

"Half the players in the NFL today train with some form of Arthur Jones' way… they just don't speak of it in those terms."

Dan Riley, Strength and Conditioning Coach, Houston Texans

NFL Case Study (Date of Onset of Protocol: February 1, 1992)
Age: 26
Height: 6'3"
Weight: 250 lbs.
Body fat: 19.3%

This professional football player desired to maintain/increase his muscular mass while reducing his body fat. Coming off reconstructive knee surgery, his reduced activity level produced a modest gain in body fat. His maintenance caloric level was determined to be approximately 4,000 calories per day. To properly reduce body fat, his maintenance caloric level was reduced by 500 calories per day.

His high intensity strength training workouts were supervised by Kim Wood (Cincinnati Bengals Strength and Conditioning Coach) and consisted of three workouts per week. He also participated in general conditioning and agility work four times per week. It also should be noted that strength coach Kim Wood's Bengals had one of the lowest injury

* During 1972-74, the Miami Dolphins set a league record for the most consecutive wins, and won two Super Bowl Championships during that time. The team's strength training regimen involved high-intensity, full body strength training 2-3 times a week as recommended by Arthur Jones, performed mostly on Nautilus equipment.

** The Washington Redskins won the Super Bowl in 1983, 1988, and 1992, while training in a full-body, high-intensity manner.

rates in the NFL, and while being both conference champions and Super Bowl participants.

(Date of Termination of Protocol: July 7, 1992)
Weight: 248 lbs
Body Fat: 10.7%

This player increased his muscular mass by 20 pounds and lost 22 pounds of body fat, demonstrating that it is possible to gain muscular body weight while modestly reducing caloroic intake to promote the reduction in body fat. Once he had achieved his body composition goal he increased his calories to approximately 4,000 per day (given his increase in muscular mass, however, this caloric level may need to be increased further).

Current Colleges and Universities & HIT

Army
Bowling Green
Cincinnati
Coastal Carolina University
Fairfield University
Florida State
Memphis
Michigan State
Michigan
Mississippi State
Missouri Southern State
Notre Dame
Ohio State
Penn State
Princeton
Providence
Saint Louis University
Siena College Stanford
Toledo
University of Illinois-Chicago
University of Detroit-Mercy
University of Maryland
University of Maryland-Baltimore County
Villanova
Western Kentucky

Michigan State Spartans: Freshman Scholarship Players

The strength and conditioning program at Michigan State, as developed and implemented by Ken Mannie, is essentially a “laboratory” of rationally-based strength training. The athletes Mr. Mannie and his associates work with are trained in ways that are consistent with the approach advocated in this book. That is, high intensity effort, emphasis on compound exercises (e.g., leg press, squats, bench press), and the careful/continuous regulation of both the volume of the anaerobic exercises performed and the frequency of workouts.

Mr. Mannie was kind enough to provide us with data on 18 of his Freshman Scholarship football players. The data tracks their training progress from September 1997 through March 1998. Using a software program (the electric coach), Mr. Mannie collects “improvement” data (i.e., the athlete’s progression with respect to resistance increase, repetition increases, or both) on a workout-to-workout basis.

Before we present these data, a couple of points need to be clarified. First, because he is training football players, a great deal of emphasis is placed upon training those body parts most vulnerable to football-related injuries (i.e., the neck, the knee, the hip/lower back structure). Although the majority of these areas are among the largest muscles in the body, they would not necessarily constitute the bodyparts focused upon by the typical weight trainee. Second, on free weight exercises (e.g., squats, bench press) Mr. Mannie does not have his athletes train to failure (i.e., one repetition short of failure). The reason for this is to reduce the chances of a training-related injury. Because free weight exercises have little provision for safety when taken to failure, Mr. Mannie does not take the risk of allowing his athlete's to train to failure ("We don't want a guy to fail with a 400 pound barbell across his shoulders.").

On exercises performed on machines, however, the athlete's go to at least positive failure on all exercises. The safety margin associated with machine exercises means that Mr. Mannie has little worry of incurring an injury by training to failure. Indeed, logic dictates that the final repetition of a set taken to failure should be the safest repetition of the set because functional strength is sufficiently weakened which greatly reduces the chances of generating enough force to be injurious to the integrity of joints and connective tissue. This assumes, of course, that impeccable exercise form continues to be employed even as the trainee approaches failure. This is more or less ensured when machines are used.

We present these data as percent improvement (i.e., increase in resistance used, repetitions, or both) reached on X sets out of Y sets attempted. For example, if an athlete performed 149 sets and improved on 105 of them, this would represent a 70.5% improvement (i.e., 105/149 = 0.7047).

Athlete	Percent Improvement
Chris Baker	60.2 % (675 of 1122)
Duron Bryan	93.8% (1044 of 1113)
Herbert Haygood	61.7% (710 of 1150)
Renaldo Hill	93.5% (977 of 1045)
Matt Kropt	90.9% (993 of 1093)
Ivory McCoy	86.1% (885 of 1028)
Joel Mesman	88.7% (968 of 1091)
Shawn Murphy	62.9% (681 of 1082)
Nick Myers	75.7% (747 of 987)
Richard Newsome	87.8% (881 of 1003)
Jace Sayler	83.1% (840 of 1011)
Demont Smith	74.5% (847 of 1137)
Josh Smith	64.2% (779 of 1214)
Artie Steinmetz	87.0% (860 of 989)
DeMario Suggs	78.0% (880 of 1128)
TJ Turner	83.7% (863 of 1031)
Marty Wensel	75.8% (774 of 1021)

As can be seen the improvement ranged from 60% to nearly 94% (average improvement of 79.5%) on the high intensity strength training protocol employed by these athletes at Michigan State. Given that these were scholarship athlete's, it is highly likely that they were engaging in some form of weight training during their high school football careers (i.e., prior to attending Michigan State). In other words, these improvements were not simply a function of training a person with little or no prior experience with weight training. As such, the argument that these athlete's would have made remarkable progress on any strength training protocol simply because they were previously untrained is not valid in this instance.

By the same token, it is important to note that, apart from their strength training, these athletes also engage in a program of overall conditioning as well as actual football-related activity. This extra physical exertion may have actually reduced the improvements they had made with their strength training. That is, it is likely that had they not been engaging in the other strenuous activities in conjunction with the strength training, their progress may have been even better.

The table below presents the changes in body weight and body composition over an eight-month period. As can be seen, in most instances these indices move in the desired direction (i.e., body weight goes down, body fat goes down; body weight increases, body fat remains unchanged or increases trivially; body weight increases, body fat decreases slightly).

	Body Weight (lbs)		**Body Composition (%)**	
Athlete	**Jan-98**	**Aug-98**	**Jan-98**	**Aug-98**
Chris Baker	259.0	248.5	21.6%	18.3%
Duron Bryan	196.5	192.5	10.2%	9.9%
Herbert Haygood	178.0	180.0	6.3%	6.8%
Renaldo Hill	168.5	168.5	5.4%	5.2%
Matt Kropt	227.0	232.0	11.9%	11.3%
Ivory McCoy	228.0	223.0	4.7%	4.2%
Joel Mesman	244.5	231.5	15.4%	13.0%
Shawn Murphy	275.5	283.5	28.8%	25.2%
Nick Myers	265.0	270.0	24.8%	21.3%
Richard Newsome	186.0	195.5	10.6%	10.2%
Jace Sayler	270.0	290.5	22.8%	24.5%
Demont Smith	167.5	166.5	5.0%	5.2%
Josh Smith	269.5	276.0	27.0%	27.8%
Artie Steinmetz	254.5	269.5	21.5%	21.9%
DeMario Suggs	188.5	187.5	7.8%	7.6%
TJ Turner	244.0	241.0	8.6%	8.1%
Marty Wensel	267.0	267.0	24.9%	24.8%

Current High School Teams & HIT

Anoka High: Minneapolis, MN
Blaine High: Minneapolis, MN
Buffalo High: Buffalo, MN
Chaska High: Chaska, MN
Coon Rapids High: Coon Rapids, MN
Edina High: Edina, MN
Fowlerville High: Fowlerville, MI
Jesuit High: Tampa, FL
Lake Forest Academy High: Lake Forest, IL
Lewman Christy High: Jackson, MI
Milaca High: Milaca, MN
Minnetonka High: Minnetonka, MN
Oak Hills High: Cincinnati, OH
Pembroke Hill: Kansas City, MO
Prior Lake HS: Prior Lake, MN
Richfield High: Richfield, MN
Shakopee High: Shakopee, MN
St. Theresa Academy: Kansas City, MO
Sykamore High: Cinncinati, OH
Troy High School: Troy, OH
Walt Whitman High: Bethesda, MD

High School Case Study (Date of Onset of Protocol: April 1, 1992)
Age: 16
Height: 6’7”
Weight: 210 lbs.
Body fat: 17.5%

This high school athlete wanted to gain strength and weight to play football at a higher level. An assessment of the young man’s diet indicated that he was consuming approximately 2,500 calories per day. It was determined that in order to gain muscular bodyweight he would need to consume approximately 4,500 calories per day. Appropriate meal plans were administered to this individual to meet those caloric needs.

Dr. Lambrinides supervised each of the young man’s strength training workouts. The workouts were performed three times per week and consisted of single sets of approximately 10 (primarily) compound exercises (e.g., squat, bench press etc.).

(Date of Termination of Protocol: June 10, 1992)
Weight: 235 lbs
Body Fat: 16%

It was determined that this individual gained 24 pounds of lean body mass and one pound of body fat. Given this significant increase in muscular mass (and its resultant effect upon his metabolic rate), his caloric maintenance requirements increased to approximately 5,500 calories per day.

Eccentric Strength Training: A 6-Week High-School Case Study*

Abstract

Negative only exercise was introduced to the strength training community in the 1970s, by Arthur Jones and with reportedly good success. During a six-week training session, eight high school football players were trained two times per week using a negative protocol that included both negative-only and negative-accentuated exercise. The overall average strength increase was 25%.

Introduction

The purpose of this study was to determine if a negative only based weight lifting program was a productive way to train high school athletes. Eight high school football players were tested for strength, measurement of body parts, and percent of body fat one week before the project. The project was conducted for six weeks with two workouts per week. Three days after the last workout, the athletes were retested, with the same measurements that were taken before the test begun.

The workouts consisted of six different exercises; five were performed negative-only (NO), one negative accentuated (raise the weight with two limbs, lower with one, NA). Only one set was performed. The set was terminated when the subject could no longer control the downward movement. The guide number of reps was eight except for chins and dips where the number was six. When eight reps could be performed, with each repetition taking ten seconds, the weight increased. The eight athletes showed an average overall strength increase of twenty-five percent.

Dr. Elliot Plese conducted a study in 1973 at Colorado State University using two subjects. The subjects performed over half of the exercises in a negative only or negative accentuated fashion. The workouts were performed three times per week for twenty-eight days. One subjected gained forty-five pounds of body weight and doubled his leg strength. Colonel James Anderson oversaw a research study titled the West Point Project in 1975. Twenty-one cadets participated in a strength program that consisted of three workouts per week, for six weeks. The strength program consisted of negative-only, negative accentuated, and normal positive-negative exercises. The cadets overall strength increased sixty percent.

To this author's knowledge no research has been conducted using an all-negative or negative-accentuated protocol on high school athletes. Is a negative based workout program performed twice per week capable of increasing strength (including concentric ability)? This study will attempt to answer that question.

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Methods

Subjects

Eight High School football players were selected for their work habits. All of the athletes were involved in weight training for at least on year. Each athlete had demonstrated the ability to work hard. The body types were one ectomorph, three mesomorphs, and four endomorphs. Athletes ranged in weight from a 252.7-pound offensive guard to a 139.8-pound wide receiver.

Procedures

Dr. Meador and Dr. Cohn administered a pre and posttest. The test consisted of seated blood pressure, pulse, and respiratory rate. The athlete was asked to jog in place for two minutes and the vitals rechecked. Measurements were taken at the neck, chest-across the nipples; both biceps flexed at right angles, waist at the belly button, both thighs nine inches from the knee, and the calves at the largest portion.

Grip strength was checked using a grip dynamometer. The athlete held the instrument in front of him with his arm straight. Three readings were taken. Tissue calcium was checked with a blood pressure cuff placed around the shin. The cuff was pumped up until the athlete complained of pain. Body fat and BMI were checked using a Bodylogic Body Fat Analyzer set on the athletic setting.

The strength test was done two days before the workouts were to begin. All strength testing was done using Hammer Equipment to eliminate skill from the test. All seat adjustments were noted and used in both the pre and posttest. The Hammer H-Squat was used to check lower body strength, the Hammer Behind the Neck Press for pressing strength, and the Hammer Front Pull-down was used to check pulling strength. The starting weight for the pre test was selected based on workouts performed earlier. The subject performed the test, going to muscular failure on each of the three exercises, and weight and reps were recorded.

The post-test was administered three days after the last workout. All medical testing and measurements were done on Monday and Tuesday, with the last workout having been performed on Friday. The strength test was conducted on Wednesday.

The workouts were scheduled twice per week, Monday and Thursday or Tuesday and Friday, for six weeks. Each workout consisted of one set of six different exercises, with two different workouts used. Negative-Attitude Equipment was used for all leg presses, pullover, rowing, and bench pressing. A Nautilus Multi Exerciser (OME) was used for chins and dips. The Hammer Neck Machine and Wrist Curl were used for those exercises.

The guide number of repetitions was eight on all exercises except chins and dips, where the guide number was six. Anytime the guide number was meet the weight was increased the next workout. For a repetition to be recorded, the weight had to be lowered in 8-10 seconds. A stopwatch with a verbal count was used. The set was terminated when the repetition was lowered in less than six seconds.

All exercises were performed in a negative only fashion with the exception of the rowing exercise. It was done in a negative accentuated style, raise the weight with two limbs, lower the one.

Chart 1. Exercises

Workout A	Workout B
1. Hammer Neck (front and back) NO	1. Neg Att. Leg Press NO
2. Neg. Att. Leg Press NO	2. Neg Att. Bench NO
3. Neg. Att. Pullover NO	3. Neg. Att. Pullover NO
4. Neg Att. Row NA	4. Neg. Att. Row NA
5. Neg. Att. Bench NO	5. Dips (Nautilus OME) NO
6. Chins (Nautilus OME) NO	6. Hammer Wrist Curls NO

Results

Chart 2. Average Results

	Pre-Experiment	Post-Experiment	Change
Body Weight	184.58 lbs (83.73 kg)	188.4 lbs (85.46 kg)	+3.81 lbs (1.73 kg)
Neck	14.75 in (37.47 cm)	15.67 in (39.80 cm)	+.92 in (2.34 cm)
Chest	36.57 in (92.89 cm)	37.85 in (96.14 cm)	+1.35 in (3.43 cm)
Biceps L	13.64 in (34.65 cm)	14.42 in (36.63 cm)	+.785 in (1.99 cm)
Biceps R	13.78 in (35.0 cm)	14.39 in (36.6 cm)	+.607 in (1.54 cm)
Waist	33.28 in (84.53 cm)	33.5 in (85.1 cm)	+.25 in (.635 cm)
Thigh L	23.85 in (60.58 cm)	24.17 in (61.4 cm)	+.392 in (1cm)
Thigh R	24.1 in (61.21 cm)	24.25 in (61.6 cm)	+.142 in (.361 cm)
Calf L	15.57 in (39.55 cm)	15.71 in (39.9 cm)	+.142 in (.361 cm)
Calf R	15.55 in (39.5 cm)	15.60 in (39.62 cm)	+.05 in (.13 cm)
BMI	25.37	25.41	+.04
Body Fat %	12.71 %	12.7 %	-.01 %
Grip L	65.7 lbs (29.80 kg)	86.65 lbs (39.30 kg)	+20.95 lbs (9.5 kg)
Grip R	70.4 lbs. (31.93 kg)	91.4 lbs. (41.5 kg)	+21.0 lbs. (9.53 kg)

Chart 2. Average Strength Test Results

Exercise	Pre-Experiment	Post-Experiment	Difference
H-Squat	343.75 lbs (155.93 kg) @ 24.1 repetitions	442.5 lbs (200.7 kg) @ 24.6 repetitions	+98.75 lbs (44.8 kg) (+29.19%)
Press	116.87 lbs (53.0 kg) @ 13.1 repetitions	139.37 lbs (63.22 kg) @ 11.1 repetitions	+22.5 lbs (10.21 kg) (19.32%)
Pulldown	140.0 lbs (63.5 kg) @ 13.1 repetitions	180.0 lbs (81.65 kg) @ 8.5 repetitions	+40.0 lbs (18.14 kg) (28.57%)

Chart 3a. Least Gains

	Pre-Exp.	Post-Exp.	Net
Body Weight	151.0 lbs (68.5 kg)	146.0 lbs (66.2 kg)	-5.0 lbs (-2.268 kg)
Body Fat %	14.7 %	17.3 %	+2.6 %
Neck	14.25 in (36.2 cm)	14.75 in (37.47 cm)	+.5 in (1.27 cm)
Chest	45.5 in (115.57 cm)	44.5 in (113.03 cm)	- 1.0 in (-0.45 cm)
Biceps L	13.25 in (33.66 cm)	13.0 in (33.0 cm)	-0.25 in (-0.635 cm)
Biceps R	12.75 in (32.4 cm)	13.0 in (33.0 cm)	+.25 in (+0.113 cm)
Waist	32.0 in (81.3 cm)	30.75 in (78.12 cm)	-1.25 in (-3.18cm)
Thigh L	28.5 in (72.4 cm)	28.0 in (71.12 cm)	-.05 in (-0.127 cm)
Thigh R	22.75 in (57.8 cm)	22.0 in (55.88 cm)	-0.75 in (-1.91 cm)
Calf L	13.0 in (33.0 cm)	13.0 in (33.02 cm)	0.0 in (0.0 cm)
Calf R	14.5 in (36.83 cm)	14.0 in (35.56 cm)	-0.5 in (-1.27 cm)
Grip R	111.0 lbs (50.35 kg)	106.6 lbs (48.35 kg)	-4.4 lbs (-1.99 kg)
Grip L	113.6 lbs (51.53 kg)	103.3 lbs (46.86 kg)	-10.3 lbs (-4.67 kg)

Chart 3b. Greatest Gains

	Pre-Exp.	Post-Exp.	Net
Body Weight	252.7 lbs (114.62 kg)	263.2 lbs (119.39 kg)	+10.5 lbs (4.76 kg)
Body Fat %	10.0 %	7.0 %	-3.0 %
Neck	17.0 in (43.18 cm)	18.0 in (45.72 cm)	+1.0 in (2.54 cm)
Chest	35.0 in (88.9 cm)	37.5 in (95.25 cm)	+2.5 in (6.35 cm)
Biceps L	13.0 in (33.02 cm)	14.5 in (36.83 cm)	+1.5 in (0.7 cm)
Biceps R	13.5 in (34.29 cm)	14.5 in (36.83 cm)	+1.0 in (2.54 cm)
Waist	32.0 in (81.28 cm)	33.5 in (85.09 cm)	+1.5 in (0.7 cm)
Thigh L	23.5 in (59.69 cm)	24.5 in (62.23 cm)	+1.0 in (2.54 cm)
Thigh R	22.0 in (55.88 cm)	23.0 in (58.42 cm)	+1.0 in (2.54 cm)
Calf L	17.5 in (44.45 cm)	18.0 in (45.72 cm)	+0.5 in (1.27 cm)
Calf R	15.5 in (39.37 cm)	16.0 in (40.64 cm)	+0.5 in (1.27 cm)
Grip R	45.0 lbs (20.41 kg)	115.0 lbs (52.164 kg)	+70.0 lbs (31.75 kg)
Grip L	37.3 lbs (16.92 kg)	105.0 lbs (47.63 kg)	+67.7 lbs (30.71 kg)

Chart 4a. Strength Improvement Least Gains

Exercise	Pre-Experiment	Post-Experiment	Improvement
H-Squat	400 lbs (181.44 kg) @ 7 repetitions	500 lbs (226.8 kg) @ 11 repetitions	+25 %
Press	115 lbs (52.2 kg) @ 5 repetitions	135 lbs (61.24 kg) @ 5 repetitions	+17.39 %
Pulldown	140 lbs (63.5 kg) @ 7 repetitions	180 lbs (81.65 kg) @ 6 repetitions	+28.57 %

Chart 4b. Strength Improvement Greatest Gains

Exercise	Pre-Experiment	Post-Experiment	Improvement
H-Squat	300 lbs (136.1 kg) @ 35 repetitions	400 lbs (181.44 kg) @ 31 repetitions	+33.3 %
Press	100 lbs (45.36 kg) @ 14 repetitions	125 lbs (61.24 kg) @ 11 repetitions	+25 %
Pulldown	140 lbs (63.5 kg) @ 16 repetitions	180 lbs (81.65 kg) @ 14 repetitions	+28.57 %

Discussion

It is possible that the strength gains could have been better if the optimum number of workouts was known. The missed workouts (due to snow) could have aided the recovery of the athletes.

The Negative Attitude equipment performed well. It would be interesting to compare a negative only workout with Negative Attitude equipment to that of negative-accentuated exercise with Nautilus or Hammer equipment.

Lastly, how would the athletes' gains been if only one workout was followed rather than two? In such a short span of time (six weeks), the athletes may have gained better if the training had consisted of the A workout only; a consideration for future research.

Conclusions

After thirty years of teaching high school weight training in a high intensity fashion, I have learned to expect a 10-15% strength increase during a semester (16 weeks). The 15% improvement is generally from the students that are supervised the closest.

The negative workouts averaged 11 minutes per session. From a time standpoint, negative workouts are a very attractive way to train. In a high school setting, where having enough time to get everything done with athletes is a problem, negative workouts may be the answer.

The eight football players showed an average strength increase of 25% from nine negative workouts. Inclement weather forced the closing of school for several days, reducing the workout days from twelve to nine. The next step is to train a group for 16 weeks with a negative protocol and document the results. The next question to answer is at what point do the workouts need to be reduced from two times per week to three times every two weeks.

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Lack of Evidence to Support Multiple Sets and Higher Volume Strength Training

In 2004, a meta-analysis was conducted on the issue of multiple set exercise and higher volume strength training routines. It was determined that there was little evidence to support the use of either method of exercise, and particularly to optimize physical conditioning and change. This meta-analysis is presented on the following 11 pages.

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Review: Resistance Training

Meta-Analyses Do Not Support Performance of Multiple Sets or High Volume Resistance Training

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ABSTRACT

META-ANALYSES DO NOT SUPPORT PERFORMANCE OF MULTIPLE SETS OR HIGH VOLUME RESISTANCE TRAINING. **Richard A. Winett JEP**online. 2004;7(5):10-20. Four recently published meta-analyses claim their results show that multiple-set resistance training protocols (higher volume) are superior to a single set of each exercise (lower volume) for producing strength gains in experienced trainees. This critique examines the framework, logic, procedures, statistics, results and interpretations of the four meta-analyses and shows that these studies did not follow many of the recognized guidelines for meta-analysis. There was very little support for any of the purported claims or conclusions. In fact, this critique suggests that simple, time efficient, single-set, lower volume protocols appear to be just as effective as multiple-set, higher volume protocols for increasing muscular strength regardless of goals or training status.

Key Words: Weight lifting; Volume; Intensity; Adaptation

INTRODUCTION

A long-term debate in resistance training is whether performing multiple sets of each exercise or a greater volume of exercise per muscle group results in greater strength gains than compared to a single set of each exercise. There is minimal evidence to support the greater efficacy of multiple sets (1), and a recent reexamination of a 40-year old study, which was perhaps the genesis of the belief in multiple sets for resistance training, revealed very little supporting evidence for the use of multiple sets (2). Nevertheless, the American College of Sports Medicine's (ACSM) Position Stand for resistance training recommends multiple sets for experienced trainees and competitive athletes (3).

Inconsistencies in results and data interpretations between different research studies can often arise due to problems with statistical power in some or all of the research at question. In an effort to overcome the statistical power limitations of prior research, researchers and academics often revert to using a meta-analysis. A meta-analysis is a quantitative way to integrate the results of empirical studies in one field, such as from resistance training studies. The purpose of a meta-analysis is to compare the outcomes produced across studies by different treatments or protocols such as strength outcomes from training with single or multiple sets. In order to be included in a meta-analysis for a given field, each study needs to have a common metric. For example, in a meta-analysis for resistance training, each study would need to have a measure of strength as an outcome of the resistance training protocol.

Each of these included studies would contribute an effect size to the meta-analysis. An effect size is a standard, statistical measure to represent the degree or amount of 'outcomes', 'impacts', or 'effects', and is quantified as a mean difference divided by the standard deviation. An effect size of 0.00 to 0.32 is considered 'small', an effect size of 0.33 to 0.55 is considered 'medium', and an effect size of 0.56 to 1.20 is considered 'large' (4). There is relevance for such categorization, and the larger the effect size the better.

Effect sizes can be calculated from each study on muscular strength produced as a result of a treatment or protocol such as training with multiple sets or training with single sets. In a meta-analysis, for example, an overall mean for all the effect sizes from studies with multiple set protocols can be compared to an overall mean for all the effects sizes for single set protocols to determine if there is a statistically significant difference between them. However, meta-analyses are only viable if they follow established methodological, statistical, and interpretive guidelines. The conclusions drawn from a meta-analysis also are only as good as the criteria used to select the prior research used in the analysis.

Four recent meta-analyses (5-8) claim their results provide convincing evidence that when the data from strength training studies are properly aggregated, the effect size for strength outcomes are considerably greater with multiple sets, or a greater volume of exercise per muscle group, compared with a single set of each exercise. It is hypothesized that these four meta-analyses are flawed and that none of these meta-analyses, logically, theoretically, or statistically provides any real evidence for the superiority of training with multiple sets per exercise or a greater volume of exercise per muscle group. It also is hypothesized that none provides clear evidence of the importance of any specific parameter of training or protocol because the four meta-analyses (5-8) generally failed to follow a number of key guidelines for meta-analyses noted by Lipsey and Wilson (9) including:

1. separating studies with differentially rigorous research designs (i.e., randomized control group designs versus nonrandomized design and other studies),
2. testing for homogeneity to determine if there is more variation in a group of categorized research studies (e.g., four sets versus two sets per muscle group) than variation expected from sampling error (indicating that the studies should not be so grouped and categorized),
3. using one mean effect size from a study and not multiple, non-independent effect sizes,
4. identifying outlier studies and effect sizes and either moderating or excluding outliers,
5. acknowledging large variation of effect sizes within a group and not just focusing on mean effect size values,
6. reporting results using confidence intervals to express a probable range of outcomes in a population, and
7. having theory guide study hypotheses with results conforming to theory or biological plausibility.

Meta-analyses have become widely used in many fields and researchers have pointed to related issues and limitations of meta-analyses. These include the need to critically examine each study in a meta-analysis to ensure the quality of each study and the accuracy of its conclusions (10); assessing and reporting the sources of bias in the studies that are included in a meta-analysis and reporting systematic bias that may exist across studies (11,12); understanding and reporting on variation of treatment effects (13-15); including moderators and mediators of treatment effects (16); exercising caution when reporting meta-analyses done with few studies and effect sizes (17) or where studies in the meta-analysis have small differences (15), and not reducing the complexity of a field and treatment effectiveness to the 'Holy Grail' of one mean effect size (12, 18).

The purpose of this document is to review each of these meta-analyses in detail while providing an ongoing critique of each study.

META-ANALYSES

Rhea et al. (5)

Rhea and colleagues (5) performed a meta-analysis that they claimed included all published and unpublished studies that were strength training interventions, though with different experimental designs, and where there was a pre- and post-training strength measurement. An examination of their extended reference list indicated that at least 26 studies meeting these criteria were not included in their analysis. These studies are cited in a recent critique of the ACSM's Position Stand (19); 24 of these 26 excluded studies showed no significant difference between single and multiple sets per exercise (19; see p. 17 Table 4). The exclusion of specific studies can create a bias in the outcomes of the meta-analysis, particularly if the reported results are consistently at odds with the conclusions of the meta-analysis.

For each study in the meta-analysis, Rhea et al. (5) reported effect sizes (*ES*) for so-called intensity (% 1 RM), frequency (number of days per week participants trained a particular muscle group), and volume (number of sets per muscle group during each session) in previously untrained and experienced (>1 year) subjects. Rhea et al. (5) reported statistically significant differences in *ES* between previously untrained and experienced trainees but it was not clear if those statistically significant differences were for intensity, frequency, or volume of training. The use of sets per muscle group compared to sets per exercise is a departure from how these studies have been analyzed and debated. However, the article contained no information about how exercises were classified by muscle groups and only one person coded sets per muscle group with, hence, no available reliability statistics. Their coding is not straightforward. For example, it is not specified whether the squat exercise is categorized as affecting the major muscle groups involved in performing the squat (gluteus, quadriceps, hamstrings, gastrocnemius, and spinal erectors), or just the quadriceps muscle.

For each study, and where possible for each variable, an effect size was generated based on the difference between a post-training and pre-training strength score divided by the pre-training strength score's standard deviation, thereby indicating the effectiveness of a given variable or treatment. Hundreds of effect sizes were generated. The result is that some studies inappropriately contributed many effect sizes while other studies contributed few effect sizes, which creates potential bias (9).

Because studies had different numbers of participants, Rhea et al. (5) used a weighting factor for the number of participants. In order for a variable to be considered, there needed to be at least 10 effect sizes from the many studies included in the meta-analysis. It also was possible to look at effects for previously untrained (<1 year training) and experienced (>1year training) participants. Rhea et al. (5) calculated an overall mean effect size for each variable for trained and untrained participants across studies.

A strength of the methodology by Rhea et al. (5) is including published (though with some published studies excluded; see above) and unpublished studies to limit the 'file draw effect' (9). File draw effects mean that studies without statistically significant outcomes are relegated to the file draw and not published. If those studies are not included, the result is that the overall effect sizes are inflated. A weakness of their methodology is not giving greater weight to studies that used sounder methodology such as randomization to conditions. Another problem is that their data presentations did not independently examine effects of one variable, e.g., sets. The sets/muscle group variable for any study from a statistical standpoint is confounded with intensity and frequency. Either joint effects should have been examined or other variables (intensity, frequency) held constant to examine one variable (sets). Coding should have been performed for percentage of 1 RM to allow for use of this variable as a moderator in the analysis.

As expected, the effect sizes for previously untrained participants were larger than those for experienced participants simply because strength increases are larger and more rapidly produced in novice trainees. Overall, the meta-analysis as reported by Rhea et al. (5), presented primarily in tables and figures with limited analyses, suggests that for experienced trainees the most effective parameters for producing strength gains are training at 80% of 1 RM (about 8 repetitions using a conventional repetition duration; see later), training muscle groups twice/week (three times/week was less effective), and performing four sets/muscle group. According to Rhea et al. (5), previously untrained people apparently produced better results training at 60% 1 RM, three times/week, and for four sets/muscle group.

The forgoing conclusions were simply based on the pattern of results and 'trend plots' (graphic representation of the data), with apparently no other main analyses reported. Such trend plots can lead to unsupportable conclusions. For example, while the effect size for experienced people using four sets/muscle group (1.17 ± 0.81) was greater than for using two sets/muscle group (0.92 ± 0.52), I performed a simple *t*-test using the study's data and found that this difference was not significant (t<1). Thus, the actual data from the meta-analysis indicated that there is no significant difference between training with two or four sets per muscle group.

A close inspection of the data presented in the meta-analysis reveals some additional points. In Table 1 (p. 458) there are data on training at different percentages of 1 RM and effect sizes for strength increases that need explanation. The effect sizes for previously trained study participants were 0.70 ± 0.65 for 70% 1 RM, 0.74 ± 0.99 for 75% 1 RM, 1.80 ± 1.30 for 80% 1 RM and 0.65 ± 0.77 for 85% 1 RM. The relatively large SD's at a given percentage of 1 RM indicate that the studies and their individual outcomes within that percentage of 1 RM differ from each other in some meaningful way. This suggests some artifact or important moderator variable that needed to be noted or analyzed by Rhea et al. (5), but was overlooked.

There also is no current theory or identifiable physiological mechanism that explains why 75% and 85%1 RM are effective stimuli, but 80% is extremely effective. What this presumably means is that if for an exercise a 1 RM is 100 kg then performing a specific number of repetitions to fatigue with 75 or 85 kg for a specific exercise is effective but performing repetitions to fatigue with 80 kg is much more effective. There is no known physiological mechanism that explains why that would that be the case. Rhea et al. (5) failed to address this issue.

Research shows there is a considerable range of repetitions that can be performed at a given RM by different individuals and with different types of resistance training movements (19). For example, in a recent training study, Chromiak and colleagues (20) found that when using 85 % of 1 RM participants were able to perform a mean of 4.5 ± 1.40 and 4.7 ± 1.70 repetitions in the bench press but 8.8 ± 4.50 and 10.8 ± 6.1 repetitions in the leg press at pre-training and post-training respectively. The different number of repetitions and the different standard deviations in different exercises at the same percentage of 1 RM call into question, as noted elsewhere (19), training models such as prescribed in the Position Stand (3) that use a specific percentage of 1 RM for a specific number of repetitions. If the data for 80% of 1 RM in the Rhea et al. (5) meta-analysis do represent some artifact, then training at *any* RM from 70% to 85% 1 RM is about equally effective. The pattern of results reported by Rhea et al. (5) makes no theoretical sense and lacks physiological plausibility.

Rhea et al. (5) did point out that the results of their meta-analysis only suggest the parameters of the most optimal protocol for strength development. Based on training status and personal goals plus other physical activities, a person could choose to perform a lower volume of training. For example, the number of sets/muscle group or training frequency could be reduced if a person has reached a point of diminishing returns as far as additional strength or muscle mass. However, there are no data presented by Rhea et al. (5) that support any particular training protocol.

In summary, the results from Rhea et al. (5) are questionable because they excluded certain published studies, used many non-independent effect sizes, focused on mean effect sizes with less attention to the large variation within a given training category, and could not explain the pattern of outcomes with any theory or physiological mechanism.

Wolfe et al. (6)

Wolfe and colleagues (6) claimed their meta-analysis showed the superiority of using multiple sets per exercise to increase strength. They performed a meta-analysis of published studies that researched the impact of single vs. multiple sets training, met at least minimal methodological criteria, and from which effect sizes could be extracted. Wolfe et al. (6) controlled for some important variables within the selected study sample such as publication bias, quality of the research design, number of people in each study, the number of effect sizes generated, and outlier status. After examination by Wolfe et al. (6), however, it was noted in their narrative that no studies so identified were excluded as outliers.

Wolfe et al. (6) approached the problem of multiple non-independent effect sizes by first including all effect sizes from one study and then also including a mean effect size from a study with multiple effect sizes. It is not clear how this approach by Wolfe et al. (6) corrected for the problem.

Surprisingly, after four decades of research in this area, Wolfe et al. (6) noted there were only 16 studies that met acceptable criteria to be included in their analyses. However, Wolfe et al. in Table 1 (pp 38-42) indicated 20 studies they included in their meta-analysis. *Only six of those studies included subjects with previous training experience.* One problem is simply the very limited number of studies from which to draw conclusions. Using a small number of studies in a meta-analysis can result in 'second order sampling error'; this is sampling error at the meta-analysis level (9).

Wolfe et al. (6) indicated that the *ES* for trained subjects was significantly greater as a result of training with multiple sets (0.70) compared with a single set (0.29), but not significantly different in untrained subjects (*ES* = 1.73 and 1.69, multiple sets and 1-set, respectively). There are though a number of other problems with the meta-analysis. Wolfe et al. (5) did not define trained. Wolfe et al. (6) noted in Table 3 that a study by Kraemer et al. (22) involved trained subjects. However, as indicated in a prior critique (19), the subjects were previously untrained collegiate female tennis players. Wolfe et al. (6) incorrectly cited the Kraemer et al. (22) publication as *Medicine and Science in Sports and Exercise*, when in fact it was published in the *American Journal of Sports Medicine.* Wolfe et al. (6) also claim that with only one exception, every study included in their analysis involving trained subjects reported that multiple sets were superior (p. 44). In a later section, the effect sizes from the studies noted by Wolfe et al. (6) are delineated and this claim is shown to be incorrect. What may arguably be small errors nevertheless question the accuracy of investigators who are attempting a much more sophisticated challenge such as a meta-analysis yielding 103 effect sizes.

Wolfe et al.'s (6) results included six studies that reported findings for experienced trainees. As noted above, the results showed that the effect size for the single set protocols was 0.29. For the multiple sets protocols, the effect size was 0.70 and there was a significant difference between these effect sizes. These data apparently show that multiple sets per exercise can be far more effective for experienced trainees. However, the studies with experienced trainees included in this meta-analysis warrant closer examination (6).

A series of experiments by Kraemer (21) contributed 10 effect sizes because data were drawn from three experiments (#2-4) in just one article. In 1997 Kraemer reported on experiments that he performed about 15 years earlier as a football coach. In experiment #2, Kraemer (21) reported that players training with single sets showed small gains expressed either as effect sizes or percent change for bench press (0.06; 4%) and leg press (0.13; 4%). Those players training with multiple sets showed greater gains in the bench press (0.13; 13%) and leg press (0.77, 19%). For experiment #3, the strength gains for the bench press for single sets (0.07; 3%) were considerably smaller than for multiple sets (0.24; 11%); similar outcomes were reported for the hang clean. For experiment #4, the strength increase in leg press (the only exercise reported with a 1RM) for single sets (.24; 6%) also was considerably smaller than for multiple sets (0.64; 18%). Such large increases in strength using multiple sets for this group of high-level strength athletes are unusual, if not questionable, and the results should be treated as outliers (9).

One other study showed differences between single set and multiple set training (22). However, as noted above, the training status of the participants at the start of the study was incorrectly designated by Wolfe et al. as experienced trainees. An examination of the study's protocol indicated that the female participants needed a period to become familiar with resistance training.

Two other studies (25, 26) with experienced trainees in the analysis are of interest. In a 13-week study where the participants trained three times/week, Hass and colleagues (25) compared one set and three sets on a training circuit of nine strength exercises. Data were presented on outcomes for five exercises. I performed a calculation of effect sizes for the two conditions in the study that showed about the same outcomes except for leg curls (0.33 for single sets and 1.0 for multiple sets). Strength gains for the experienced trainees were approximately 10% regardless of the protocol used (one or three sets). There was a significant increase across all exercises as a result of performing one set or three sets of each exercise, with no reported significant difference in strength outcomes between one set and three set groups.

Ostrowski and colleagues (26) compared protocols involving one, two, or four sets per exercise. Each exercise was performed once/week and the participants trained four times/week using a split routine. Participants performed three exercises/muscle group so that some people were performing as few as three sets/muscle group/week (1-set group) while others were performing up to 12 sets/muscle group/week (4-set group). At the end of the study, there were no significant differences in outcomes among the groups. The strength gains were about 6%, more or less what can be expected with experienced trainees, for the bench press and squat exercises. Ostrowski et al. (26) concluded that reaching a *minimum* of volume and frequency of training is all that is required to produce positive outcomes.

Interestingly, the outcomes from Hass et al. (25) and Ostrowski et al. (26) were similar even with different exercise modalities, volume, and frequency of training. Despite what appear to be large differences in protocols, they all commonly provided an adequate stimulus and then recovery time for adaptation. The one set/exercise routines used by Hass et al. (25) and Ostrowski et al. (26) demonstrate that experienced trainees can benefit from simple, time efficient resistance training routines.

The difficulty in drawing definitive conclusions about single versus multiple sets with experienced trainees, particularly given the small number of requisite studies, is further illustrated by the following analyses I performed using the data presented in Wolfe et al. (6). Effect sizes from each of four studies (23-26) represented the mean effect size across different exercises performed for either single or multiple sets in experienced trainees. Each study provided just two effect sizes, one for single and one for multiple sets as is appropriate (9), and not the multiple non-independent effect sizes from each study of the six studies (21-26) as in the meta-analyses by Rhea et al. (5) and Wolfe et al (6). From the Ostrowski et al. study (26), I used the mean effect size for one and four sets because the mean effect size for four and two sets was about the same. I represented the data using confidence intervals. Given the data from the studies, confidence intervals indicate the range within which the population mean is likely to lie. I used a 95% confidence interval indicating that there is a 95% probability that the mean is within the ranges noted. The mean effect size and confidence range from these four studies (23-26) were for single sets, 0.44 ± 0.22 ($p = 0.05$) and for multiple sets, 0.64 ± 0.25 ($p = 0.05$). Expressed in confidence ranges ($p = 0.05$), these four studies suggest an effect size range of 0.22 to 0.66 for single sets and 0.39 to 0.89 for multiple sets. These are overlapping distributions. When the mean effect size for the single set (0.14) and multiple sets outcomes (0.45) from Kraemer's (21) three experiments were added into the pool, the overall single set effect size was then 0.38 ± 0.27 ($p = 0.05$) with a range of 0.11 to 0.65, and the multiple set effect size was 0.60 ± 0.26 ($p = 0.05$), with a range of 0.34 to 0.86, which again suggests overlapping distributions. When the mean single set effect size (0.28) and the multiple set effect size (1.27) from the study (22) where the training status of the participants was incorrectly noted as experienced were added, the overall mean effect size for single sets was 0.36 ± 0.26 ($p = 0.05$) with a range of 0.10 to 0.62, and for multiple sets 0.71 ± 0.46 ($p = 0.05$), with a range of 0.25 to 1.17, and remain overlapping distributions. Which studies are included, whether a mean effect size from each study or multiple non-independent effect sizes are drawn from each study, and how analyses are conducted impact conclusions that are drawn. The aforementioned confidence intervals (9) do not indicate the superiority of multiple sets.

The results from Wolfe et al. (6) are questionable because only a small number of studies involved experienced trainees (21-26), Wolfe et al. did not critically examine each study, and multiple non-independent effect sizes were used.

Rhea et al. (7)
With very little reported data, Rhea et al. (7) claimed that their meta-analysis demonstrated that 3-set training was superior to 1-set training in previously untrained and previously trained participants. They did not define how they coded trained and untrained participants. Standard deviations were large (i.e., overall ES = 0.28, SD = 0.56), indicating a large variation of effects from training with either one or three sets. Rhea et al. (7) used 16 studies in their analysis; 12 of them are cited in a prior critique (19), and nine out of those 12 studies reported no significant difference in strength gains as a result of single or multiple sets (Table 4, p. 17). One of the other three studies is the previously discussed outlier by Kraemer (21). Of the four other references used by Rhea et al. (7), one (27) was published after the Position Stand (3) and reported that the strength gains in the leg press exercise were significantly greater in a 3-set group compared with a 1-set group, with no significant differences in bench press strength, lean body mass, percent body fat, or chest and thigh circumference. The other three references (28-30) were abstracts that all reported no significant differences in strength gains as a result of training with one set or three sets. Therefore, 12 of the 16 studies in the meta-analysis (7) reported no significant difference between single and multiple sets. These points alone raise questions about this meta-analysis that claims training with three sets is superior to training with one set per exercise.

Rhea et al. (7) generated an effect size estimate by considering the one set group as the 'control group'. The outcomes of this meta-analysis, as noted, suggested the superiority of using three sets/exercise compared to one, with a mean effect size of 0.28 ± 0.56. Rhea et al. (7) also compared mean effect sizes that had equated intensity and controlled variation (0.70 ± 0.92) to those that did not equate intensity and variation (0.2 ± 0.70) and found that this difference approached significance (p = 0.12*)*. The large standard deviations and a significant test for homogeneity indicate other variables impacted outcomes and the likely presence of outliers. There is some question about interpreting mean effect sizes in the presence of a significant test for homogeneity because this means that there is a great deal of variability associated with the effects of a treatment (9).

One of the major problems noted in the review of the prior Rhea et al. (5) meta-analysis pertains here as well. A total of 93 effect sizes were generated from only 16 studies in this second meta-analysis by Rhea et al. (7). Given these problems in their meta-analysis, Rhea et al. (7) actually have no clear support for multiple sets.

Peterson et al. (8)
Peterson et al. (8) reported 37 training studies that had pre- and post-training strength measures in competitive athletes. The studies were apparently a subset of studies from the Rhea et al. (5) meta-analysis and the methodological problems noted above for Rhea et al. (5) pertain to Peterson et al. (8) as well. Effect sizes were generated for every strength outcome, using the formula post-training mean minus pre-training mean divided by the pre-training standard deviation. Studies could have multiple effect sizes because they had multiple outcomes such as strength gains for squats, bench press, and pull-down exercises. As noted above, such use of many non-independent effect sizes is not appropriate (9).

Peterson et al. (8) categorized the training protocol in each study for number of sets per muscle group, training at a specific percentage of 1 RM, and training muscle groups two or three days/week. For each of these variables (sets, percentage of 1 RM, frequency of training), there were mean effect sizes from the different studies. For example, using four sets/muscle group, the mean effect size was 0.90 (±1.32; indicating a very good impact but with a large standard deviation and, thus, much variation of outcomes) derived from 119 effect sizes from the different studies. The mean effect size for five sets was 0.64 ± 0.73 from 37 effect sizes, and for six sets, 0.68 ± 0.74 from 26 effect sizes. The mean effect size for 8 sets was

1.22 ± 0.56 but that was based on only six effect sizes, possibly from the same (one) study. Effect sizes for 12 (0.69), 14 (1.06), and 16 (0.41) sets were smaller but with no consistent pattern.

Peterson et al. (8) claimed that their meta-analysis showed a continuum of strength increases elicited by a continuum of increased training volume, but the actual data from their meta-analysis do not support their claim. Peterson et al. (8) also claimed that their meta-analysis showed that competitive athletes should use eight sets/muscle group. An inconsistent pattern of results and the small number of effect sizes for eight sets also makes this conclusion questionable.

A somewhat similar, inexplicable pattern emerged in the analysis by Peterson et al. (8) for training at a specific percentage of 1 RM. The effect size for training at 70 % 1 RM was 0.07 ± 0.06, indicating there is *no* impact on strength, whereas for 75 % 1 RM, the mean effect size was 0.73 ± 0.87, for 80 % 1 RM, 0.57 ± 0.69), and for 85% 1 RM, 1.12 ± 1.35), which is a large effect size but with a very large SD. The differences in both effect sizes and their standard deviations in the training range of 70-85 % 1 RM are puzzling. There is no theory or physiological mechanism explaining why a 5 % change in resistance and doing a few less or a few more repetitions can result in such large differences in outcomes. This result also is subject to some questioning because, as previously noted, people can vary a great deal by how many repetitions they perform to exhaustion for a specific exercise with a given RM (20).

Peterson et al. (8) also indicated that the overall outcomes were moderated by use of creatine, periodized training, and training to failure. These variables were reported in the narrative as eliciting statistically significant greater strength gains but no specific data were presented.

Another limitation was how the data were analyzed. Peterson et al. (8) presented the graphic outcomes of the data with no other formal analyses. Unless separate analyses were done between, for example, every number of sets, it is not known where, if any, there was a significant difference. In the absence of any obvious pattern, no clear conclusion can be reached. Furthermore, given that there were only six effect sizes contributing to the mean for eight sets, with those effect sizes possibly from one study, any conclusion about the impact of eight sets compared to any number of other sets is highly suspect. In addition, the mean for four sets was compiled from 119 effect sizes. Therefore, the two mean effect sizes for eight versus four sets cannot be legitimately compared.

For the sake of clarity, however, using the data from Peterson et al. (8), I statistically compared the difference between four and eight sets/muscle. The difference is not significant ($t<1$).

The results from Peterson et al. (8) are highly questionable because of their use of multiple non-independent effect sizes, the few effect sizes available for the category claimed to produce superior results (8 sets), their focus on mean effect sizes and not the large variation, and the lack of any theory or a physiological mechanism explaining their pattern of outcomes.

CONCLUSIONS

Four recent meta-analyses claim that their results show the superiority of using multiple sets or using four or more sets per muscle group compared with a single set per exercise in experienced trainees or competitive athletes. The pattern of results, the statistics presented in the studies, the statistics I performed for three meta-analyses (Rhea et al; 5; Wolfe et al; 6; Peterson et al; 8), an examination of the studies in one meta-analysis (Wolfe et al; 6), and an absence of any explanatory theory or physiological mechanism, *all fail* to support high-volume resistance training protocols or recommendations.

Table 1 shows the recommended guidelines for meta-analyses and whether each meta-analysis followed or did not follow a specific guideline. It is readily apparent that most of the basic guidelines (9) and cautions and caveats (10-18) for performing meta-analyses and presenting their data were not followed in the aforementioned meta-analyses (5-8).

Table 1. Adherence to Specific Meta-Analysis Guidelines

Guidelines	**Reference**			
	Rhea et al. (5)	***Wolfe et al. (6)***	***Rhea et al. (7)***	***Peterson et al. (8)***
Categorize Studies By Quality	No	Yes	No	No
Examine Each Study's Results and Conclusions	No	No	No	No
Test For Homogeneity	No	Yes	Yes*	No
Include All Relevant Studies	No	Yes	Yes	?
Control For Publication Bias	Yes	Yes	?	?
Use One Mean Effect Size Per Study	No	No	No	No
Precise Coding of Effects of Exercise or Trainee Status	No	No	No	No
Identify and Exclude Outliers	No	No	No	No
Acknowledge And Report Large Variation	No	No	No	No
Use Formal Statistics	No	Yes	Yes	No
Use Confidence Intervals to Report Results	No	No	No	No
Use Moderators in Addition to Gender, Age, Trainee Status	No	Yes	Yes	Yes
Caution in Conclusions When Using Few Studies	No	No	No	No
Use Theory or Physiological Mechanisms To Explain Results	No	No	No	No

? = Unclear.; *Significance test for homogeneity completed but no results presented.

The major questions are 'how' and 'why' these meta-analyses (5-8) were published with such obvious flaws. One answer to the 'how' question is that across disciplines, researchers have become enamored with meta-analyses that seem to be able to reduce the complexity of a field to a single number (9,18). This critique of these four meta-analyses shows that each meta-analysis by itself can be complex and when guidelines (9-18) for meta-analyses are not followed, the results can be incorrect and misleading.

One answer to the question of 'why' these studies were published is that their unchallenged claims support one facet of the current paradigm delineated in the ACSM Position Stand (3), which is that a greater volume of exercise elicits a greater increase in strength. However, the actual data and some of the studies within these meta-analyses indicate otherwise. Contrary to the prevailing, yet unsubstantiated belief about higher volume training (3), lower volume, time efficient protocols, such as a single set of nine exercises three times/week (25), appear effective regardless of training status and goals.

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Review

STRENGTH TRAINING METHODS AND THE WORK OF ARTHUR JONES

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ABSTRACT

STRENGTH TRAINING METHODS AND THE WORK OF ARTHUR JONES. **Smith D, Bruce-Low S**. **JEP**online. 2004;7(6):52-68. This paper reviews research evidence relating to the strength training advice offered by Arthur Jones, founder and retired Chairman of Nautilus Sports/Medical Industries and MedX Corporation. Jones advocated that those interested in improving their muscular size, strength, power and/or endurance should perform one set of each exercise to muscular failure (volitional fatigue), train each muscle group no more than once (or, in some cases, twice) per week, perform each exercise in a slow, controlled manner and perform a moderate number of repetitions (for most people, ~8-12). This advice is very different to the strength training guidelines offered by the National Strength and Conditioning Association, the American College of Sports Medicine and most exercise physiology textbooks. However, in contrast to the lack of scientific support for most of the recommendations made by such bodies and in such books, Jones' training advice is strongly supported by the peer-reviewed scientific literature, a statement that has recently been supported by a review of American College of Sports Medicine resistance training guidelines. Therefore, we strongly recommend Jones' methods to athletes and coaches, as they are time-efficient and optimally efficacious, and note that, given his considerable contribution to the field of strength training, academic recognition of this contribution is long overdue.

Key Words: Weight training, Bodybuilding, Power, Muscular endurance, Nautilus, MedX

INTRODUCTION

During the past thirty or so years, the popularity of weight training has increased enormously. Simultaneously, the number of popular books and articles devoted to this topic has also increased, and those interested in improving their muscular size and strength are confronted by a rather bewildering array of information sources, many of which appear to contradict one another. Issues such as how many sets and repetitions individuals should perform, the movement cadence individuals should adopt, frequency of training, and how to specifically target increased power or muscular endurance are discussed regularly in popular weight training magazines and books, with little in the way of agreement between the individuals writing in such publications.

In contrast, an examination of recent exercise physiology textbooks (1-3), most specialist strength and conditioning textbooks (4-10) and of the guidelines produced by certification organisations such as the National Strength and Conditioning Association (11) and the American College of Sports Medicine (12) reveals an apparent academic consensus as to how individuals should perform weight training for optimal results. The guidelines issued by such sources state that experienced trainees should perform –

1. multiple sets of each exercise for best results,
2. low-repetition sets to increase strength and high-repetition sets to increase muscular endurance, and
3. repetitions explosively (i.e. with a relatively fast cadence) for optimal power development.

Also, they argue that for experienced trainees, very frequent, high-volume training up to 4-5 days/week twice/day, for a total of around 21 hours of training/week (12) will produce best results.

However, this consensus on optimal strength training methods is not shared by everyone in this field (13-20). A recent article has, for instance, criticised the ACSM resistance training guidelines for their lack of empirical support (13), and another paper (14) has pointed out that despite claims to the contrary, the available evidence does not favour the multiple-set approach advocated by the ACSM and NSCA. Such criticisms are, however, not new. One individual, who has been offering advice directly contradicting all of the above recommendations for over thirty years, is Arthur Jones, founder and retired Chairman of Nautilus Sports/Medical Industries and MedX Corporation. In the early 1970s, when Jones first developed his Nautilus exercise equipment, he began to publish advice as to how to use this equipment for best results. However, the advice he gave can be (and was intended to be) utilised by those using any kind of weight training equipment. This advice was published in over 100 articles within various fitness magazines and technical journals, and in several books, between 1970 and 1998. Jones' recommendations (15-20), aimed at anyone wishing to increase muscular strength, hypertrophy, power and endurance, can be summarised as follows:

1. Perform one set of each exercise to muscular failure. Additional sets will not provide better results.
2. Train each muscle group no more than twice/week, and many individuals will produce optimal results from training each muscle group no more than once/week.
3. Move slowly and deliberately during each exercise. Such exercise form will produce optimal increases in strength and power.
4. For most individuals, best results will be achieved by performing a moderate number of repetitions (around 8 to 12) rather than very high or low repetitions. This will produce optimal increases in muscle strength and endurance, which are related in that increases in strength will be accompanied by increases in muscular endurance.

Therefore, in summary, Jones' recommendations are to train hard (to muscular failure) but relatively briefly and infrequently to optimise muscular strength, hypertrophy, power and endurance. In contrast to the recommendations of many exercise physiologists, who advocate strength training programs that can consume upwards of twenty hours/week (8,11), Jones recommends training for a maximum of about 90 min/week. It is important to note here that Jones' work has never been published in peer-reviewed scientific journals. Some physiologists have pointed this out in an attempt to discredit Jones' theories (21,22). However, the aim of this article is to point out that his hypotheses have mostly been strongly supported by the peer-reviewed scientific literature. This is in great contrast to the recommendations made in many exercise physiology textbooks and by some prominent exercise certification organisations, which appear to have very little scientific support, and which a great deal of scientific evidence clearly contradicts. The following sections examine the scientific literature relating to each of Jones' training recommendations.

REVIEW OF RESEARCH

Single Versus Multiple Sets

From his earliest writings (15) to his final ones (20), Jones argued that optimal increases in muscular strength and hypertrophy can be produced from one set carried to a point of momentary muscular failure (muscular failure), and that further sets are therefore unnecessary. For example, in his book *The lumbar spine, the cervical spine and the knee: testing and rehabilitation* (18, p. 44), he stated:

"*How many sets of the exercise? One. Additional sets usually serve no purpose and may produce a state of overtraining with some subjects…The exercise should be stopped when the subject is no longer capable of completing a full-range movement without jerking*"

In contrast, the most recent editions of many popular textbooks (1,4,6,8), and the guidelines of both the NSCA (11) and ACSM (12), advocate the performance of multiple sets of each exercise for best results. For example, Watson (3) suggests that although single sets are useful for beginners *"...the superiority of the multiple-set system has been demonstrated, and this method of training is appropriate for experienced strength trained athletes*" (p. 97). Fleck and Kraemer (8) claim, "*...a single-set system may not promote the cellular adaptations required to support long-term gains in strength and power*" (p. 119). In examining this literature, we have been unable to find a single general exercise physiology textbook that recommends single-set training although Wilmore and Costill (7) and Powers and Howley (23) suggest there is ambiguity within the literature regarding single versus multiple-set training. However, some strength training textbooks (24-27) do recommend single sets.

This general bias in favour of multiple sets is very interesting, given that the great preponderance of scientific studies show that single sets produce results at least as good as those produced by multiple sets, both in previously trained and untrained subjects. For example, Starkey et al. (28) observed there were no significant differences when knee extension and knee flexion were examined with groups that either undertook training 3 days/week utilising either high volume (3 sets) or low volume (1 set). Peak isometric knee extension torque increased by 15.1 % and 14.8 %, and knee flexion by 13.9 % and 16.2 %, using 1 and 3 sets, respectively. In addition, Starkey et al. also reported significant increases in muscle thickness, with no significant between-group differences. Vincent et al. (29) found that a single-set group increased the weight used on the MedX knee extension by 25.6 %, with an increase in peak isometric torque of 35.4 %, whereas a three-set group increased weight used by only 14.7 %, with an increase in torque of 32.1 %. Again, none of these differences were significant.

This was also true of Ostrowski et al. (30) whose subjects used a 1, 2 or 4 set protocol for 10 weeks. There were significant increases in strength for all groups for 1 RM squat (7.5, 5.5 and 11.6 %), 1 RM bench press (4.0, 4.7 and 1.9 %) and bench press power (2.3, 2.3 and 3.1%) for the 1, 2 and 4 set groups respectively. There were no significant differences between the 3 groups. In addition, there were also significant increases in tricep brachia thickness (2.3, 4.7 and 4.8 %), rectus femoris hypertrophy (6.8, 5.0 and 13.1 %), rectus femoris circumference (3.0, 1.5 and 6.3 %)

and body mass (2.0, 2.6 and 2.2 %) for the 1, 2 and 4 set groups respectively, although there were no significant differences between the groups.

Pollock et al. (31) showed that single-set training produced very large increases in lumbar extension strength. After a 10-week training program their subjects showed at 0^{o} (full extension) and 72^{o} (full flexion) an increase in strength of 102 % and 42 % respectively when compared to the non-exercising control group. Further work by Pollock et al. (32) showed that a single-set training programme is all that is required in order to obtain an increase in cervical extension strength. The relative percent increases in cervical extension strength observed when subjects trained using 1 set of dynamic exercise either once or twice a week were 35% and 40.9% respectively. This is supported by the findings of Tucci et al. (33) who also observed significant increases in lumbar extension strength following 10 or 12 weeks training when using single-set training. Tucci et al. also observed that this increase in strength can be maintained for an additional 12 weeks by reducing the training frequency to either once every 2 weeks or once every 4 weeks, compared to a 55 % reduction in lumbar strength in subjects who stopped training altogether.

Haas et al. (34) examined the effects of two different strength-training protocols (either 1 or 3 sets of nine exercises, performed three times/week for 13 weeks) on experienced weight trainers who had been training for an average of 6.2 years. Both groups increased isometric knee extension and knee flexion torque, lean body mass and chest and biceps circumference, with no between-group differences on any of these variables.

In a review published in 1998, Carpinelli and Otto (35) concluded that the research to date strongly supports the idea that single sets can produce optimal results. This was the case in 33 out of the 35 studies they reviewed. Carpinelli (36) pointed out that many exercise physiology textbooks cite a 1962 study by Berger (37) as supporting multiple-set training. This study found a small advantage from performing multiple sets on bench press one-repetition maximum (1 RM; 22.3 % increase from 1 set versus a 25.5 % increase from 3 sets, a 3 % difference in strength from 300 % more training). Carpinelli revealed that the subjects in this study were performing other weight training exercises during the study, and Berger did not control the number of sets and repetitions performed on these exercises. Rest times and movement speed were also not controlled. Also, there was no control for exercise intensity: subjects simply performed a designated number of repetitions. All these confounding variables call Berger's conclusions regarding the supposed superiority of multiple sets into question. Therefore, in contrast to Arthur Jones, whose views have been empirically validated by a great deal of peer-reviewed research, many exercise physiologists appear to be making recommendations based on one forty-two-year-old study with numerous confounding variables.

Many of the references cited in books and articles supporting multiple-set training are themselves books and not research studies, and therefore amount to personal opinion rather than scientific evidence. For example, Wathen (38) supports the use of multiple sets using references that are books as opposed to research studies (for example, 39-42). Finally, other studies that have been cited (12,43) as supporting multiple sets are those of Kraemer (44), Kraemer et al., (45), Kramer et al. (46) and Marx et al. (47). However, the results of these studies all have something interesting in common. That is, the results produced by single-set training seem remarkably poor compared to most of the findings in the literature noted above. For example, in Kramer et al.'s 1997 study, the average increase in subjects' 1 RM squat following a 14-week training program was less than 12 %. Contrast this with the findings of Pollock et al. (29), where the lumbar extension strength of subjects more than doubled in the fully flexed position from one set to muscular failure performed once/week for 10 weeks. Hurley et al. (48) demonstrated a 50 % increase in lower body strength and a 33 % increase in upper body strength from a 16-week training regime consisting of a single-set of each exercise to muscular failure. From a similar training regime, this time lasting just 10 weeks, Messier and Dill (49) showed a 30 % and 46 % increase in upper body and lower body strength respectively. In contrast, in the Kraemer et al. (45) study no strength increases occurred after the fourth month of a nine-month training programme. Marx et al. (47) found no strength increases after the 12th week of a 24-week program. One strength coach experienced in single-set programs has commented that such poor results from single-set training make such data rather suspect: that the subjects may not have been supervised adequately (50). One of the authors of the present paper is a former strength coach who has personally trained many athletes and has never experienced strength increases as poor with any one individual as the averages reported in these several studies. In one case (44) there is clear evidence of researcher bias. That is, with one important dependent variable reported by the author, 1 RM hang clean, the multiple-set group practiced this exercise as part of their training protocol but the single-set group did not. Also, two other exercises (leg press and bench press) were performed in 33 % more workouts by the multiple-set group than by the single-set group. Finally, the single-set group performed sets of 8-12 repetitions throughout the study whereas the multiple-set group performed some sets with 3-5 repetitions, again potentially biasing the results of the 1 RM tests. That is, the multiple-set group may well have performed better in the 1 RM tests because the multiple-set subjects were more used to performing low-repetition sets. It appears that this author, whose opposition to single-set training is very clear from the tone of this paper, has allowed his personal preference to influence his research design.

The Marx et al. (47) study also contained numerous confounding variables. In this experiment, untrained females were allocated to either a single-set or multiple-set group for a six-month training programme. The single-set group performed one set of 8-12 repetitions on each of ten machine exercises three times/week, whereas the multiple-set group performed 2-4 sets of free weight and machine exercises four times/week, with varying repetition ranges (8-10 reps twice/week, and a mix of 3-5 reps, 8-10 reps and 12-15 reps twice/week). The multiple-set group showed a significantly greater increase in strength than the single-set group on the I RM leg press and bench press, and a significant increase in lean body mass, which the single-set group failed to demonstrate. However, there are several serious design flaws in this study. First, the multiple-set group practiced both exercises that were used as dependent variables during the study, whereas the single-set group only practiced one of these exercises. Also, as in the Kraemer (44) study, the low-repetition sets practiced by the multiple-set group may have given that group an advantage in the 1 RM strength tests. Finally, the differing training modalities used by the two groups (i.e. free weights and machines versus machines only) may also have confounded the results.

To ensure a valid test of the hypothesis that single and multiple sets will produce differing physiological effects, the only variable that should differ between groups is the number of sets: where this requirement has been met, single sets have almost always been shown to be at least as effective as multiple sets (26-28,32). The only exception is a study by Borst et al. (51), who found that a three times/week training program produced significantly greater strength increases when three sets of each of the seven exercises were performed compared to one set. However, neither group significantly increased body mass or changed body composition, suggesting that though the greater practice gained by the three set group facilitated greater improvement in the performance of the exercises, neither protocol was effective in producing myogenic effects. Therefore, an appropriate conclusion from this would seem to be that the three times/week regimen used was not very effective regardless of whether three sets or one set of each exercise were performed.

The authors of two recent meta-analyses (52,53) claim that their findings support the superiority of multiple sets. Both meta-analyses claim to include all relevant published studies. In the 2002 paper (52), the authors analyse 16 studies that have examined the effects of weight training programmes comprising one and three sets per exercise respectively. The 2003 paper (53) compares the results of 140 studies that have examined the effects of strength training interventions, in an attempt to determine how many sets per muscle group are best. The two meta-analyses in question compare many studies loaded with potentially confounding variables. These include varying numbers of repetitions, different exercises and training modalities, different training intensities (i.e. some studies specify training to muscular failure and others don't), different strength measures, different subject populations (healthy and diseased, sedentary and athletic, young and old), and different dietary constraints. The idea that one can meaningfully compare studies with so many differences is clearly questionable. It is also important to point out that the great majority of the studies in the 2003 meta-analysis were not designed to compare the effects of single and multiple-set weight training: they were actually designed to examine such widely differing topics as the effects of various nutritional supplements, the effects of weight training in different age groups, changes in cardiovascular function as a response to weight training, specificity of training, effect of weight training on bone mineral density, balance, walking speed and many other variables. We contend that comparing such a hodgepodge of studies will simply not provide meaningful results: the idea that the differences between the studies will somehow magically even themselves out to produce a balanced comparison of different training volumes appears very naïve. Indeed, researchers have previously criticised this sort of abuse of meta-analysis ('comparing apples and oranges'; 54,55).

The confounding variables mentioned above make these meta-analyses a questionable exercise at best, even if the studies included were well-designed and controlled, and represented all such published studies. However, neither of these conditions is met. Firstly, the paper includes the Berger (37), Kraemer (44), Kraemer et al. (45) and Kramer et al. (46) studies, the numerous shortcomings of which have been discussed above.

Of even greater concern is the fact that many studies are missing from the analyses of Rhea and colleagues. In the 2002 study, supposedly all English-language studies, including abstracts, published by 2000 and comparing one versus three sets/exercise programs were included. However, this is not the case. At least six studies published prior to 2000 that examined this topic are not included in their meta-analysis. Interestingly, none of these studies found any advantage in performing multiple sets. It is a remarkable coincidence that all these studies ignored by Rhea et al. do not support their conclusions. For example, the Vincent et al. study noted previously is missing from the analysis, as are studies by Terbizan and Bartels (56), Stowers et al. (57), Westcott et al. (58), Welsch et al. (59) and Stadler et al. (60).

Given that only 16 studies were included in the analysis, it is likely that the inclusion of these six studies would have had a major impact on the findings. A similar phenomenon has occurred in their 2003 analysis. That is, a number of studies showing very large strength increases from single-set training are absent. These include the six studies noted above, but also a number of others that again are likely to have impacted upon the results of the meta-analysis. These include the studies by Pollock et al. (31,32), Tucci et al. (33), Graves et al. (61) and Carpenter et al. (62) mentioned elsewhere in this paper, and other studies by Risch et al. (63), Highland et al. (64), Peterson (65), Holmes et al. (66), Ryan et al. (67), Koffler et al. (68), Rubin et al. (69), Capen (70) and Westcott (71). It appears very suspicious that all these studies that have not been included in the meta-analysis have found single-set training to be very effective. It is also remarkable that three studies that were included in the 2002 analysis (72-74) are absent from the 2003 one. In total, therefore, 23 studies, all of which found single-set training to be very effective, are missing from the 2003 analysis. We do not wish to speculate on the possible reasons for these omissions, but simply note that such omissions, in conjunction with the methodological problems noted above, render the authors' conclusions invalid.

Another important point regarding the 2003 analysis is that the study compared single versus multiple sets per muscle group, not per exercise. It is important to note that those advocating one set per exercise, including Jones, do not usually hypothesise that one set for every muscle group would lead to optimal muscle gains. Also, in a well-balanced training program it would be almost impossible to only perform one set/muscle group, as many exercises work more than one muscle. Therefore, these researchers have constructed a 'straw man' (one set/muscle group) to knock down, presumably knowing that most single-set trainees, although performing one set/exercise, perform more than one set/muscle.

Overall, it is clear that the great majority of well-controlled, peer-reviewed studies support Jones' (15,16,18-20) contention that one set per exercise is all that is necessary to stimulate optimal increases in muscle strength and hypertrophy. Though there are exceptions in the research literature, these are few and most suffer from confounding variables and, in some cases, blatant experimenter bias.

Optimal Training Frequency

It is often suggested in the exercise physiology literature that novices train two to three times/week, but that more experienced trainees should engage in more frequent training. For example, the ACSM (12) recommend that advanced bodybuilders, powerlifters and weightlifters should perform a "split" routine (training different muscle groups on different days) involving training four-six days/week, two or three times/day. In a NSCA publication, Binkley (75) also argues that, in the off-season, athletes should perform weight training four-six days/week. Fleck and Kraemer (8) state that in order to increase strength, maximal voluntary muscular actions should be undertaken on a daily basis. They also state that more frequent training sessions result in greater increases in strength. These recommendations contrast vividly with the views of Jones, who in his early work (14,15) advocated training the whole body three times/week, later amended to training each muscle group only once or, at most, twice/week (20). "How many weekly workouts? Not more than two, and some people will produce better results from only one weekly workout. More is not always better, and in the case of exercise is usually worse" (p. 559).

Given the very time-consuming nature of the training methods advocated by the NSCA and others, it seems reasonable to assume that strong scientific proof must have been found to justify their adoption of such methods. At least, the preponderance of scientific evidence must have shown that this high frequency of training produces significantly better results than the lower frequency advocated by Jones. However, a search of the scientific literature will clearly disappoint those who expect bodies such as the NSCA to base their training practices on objective scientific evidence rather than subjective personal preference. For both novice and experienced trainees, there appears to be very little support for the notion that training each muscle group more than once (or in some cases twice)/week provides any additional benefits. For example, Graves et al. (61) examined the effects of 12 weeks of resistance training on the lumbar extension strength of untrained subjects, who performed one set of lumbar extensions either once, twice or three times/week, or once every two weeks. All groups increased significantly in peak isometric torque at all seven joint angles tested, and there were no significant between-group differences in isometric strength increases. These findings were replicated by Carpenter et al. (62). Interestingly, one of the subjects in the three times/week group in the Graves et al. study actually produced large losses in strength from overuse atrophy. This subject was repeatedly forced to reduce the level of resistance to enable her to perform the required repetitions. This illustrates the large inter-individual responses that can occur in exercise tolerance, and the importance of cautiously regulating the frequency of strength training exercise according to the individual's tolerance. However, this issue is not discussed in the NSCA (11) or ACSM (12) guidelines, and NSCA publications (75) offer 'canned' training program with no attention given to the importance of individualising such programs based on the tolerance for exercise which, as the above example shows, can vary dramatically between individuals. Thus, such programs may produce good results for some individuals and very poor results for others. It is also worth noting that Binkley (75), who makes a number of points directly contradicted by the research discussed in this paper, makes no reference to any peer-reviewed scientific research, referencing only four books, all of which were authored by other NSCA advocates.

Similarly to Graves et al. (61) and Carpenter et al. (62), Pollock et al. (32) examined the effects of one set of cervical extensions performed either weekly or twice-weekly, and again found that both protocols significantly increased isometric cervical extension strength, with no significant difference in strength increases at seven of the eight joint angles tested. Of course, it could be argued that such findings may only be applicable to the lumbar and cervical spine muscles. However, when Taafe et al. (76) examined the relative effectiveness of training the whole body once, twice or three times/week for 24 weeks, they found no significant differences in strength increases generated by the three protocols on any of the five upper body and three lower body exercises performed.

For some subjects, it appears that training twice/week produces better results than training three times/week. Carroll et al. (77) compared the effects of training twice/week and three times/week for a total of 18 sessions (i.e. the twice/week group trained for nine weeks and the three times/week group trained for six weeks). Although both groups gained significantly in 1 RM squat, with no significant between-group difference, only the twice/week group increased significantly in isometric and isokinetic knee extension strength; the three times/week group did not increase on either measure.

Optimal training frequency may also differ between muscle groups. DeMichele et al. (78) examined the effect of one set of MedX torso-rotation exercise, performed either once, twice or three times/week for 12 weeks, on isometric torso rotation strength. No significant differences in strength gains were found between the twice and three times/week groups, but both increased to a significantly greater degree than the one time/week group.

What of training frequencies of greater than three times/week? Rozier and Schafer (79) examined the effects of training three and five times/week respectively on the knee extension strength of previously untrained females. In this study, the three times/week group showed greater increases in both isometric and isokinetic torque than the five times/week group, though these differences were not statistically significant. In contrast, in a study that has been discussed previously in the single versus multiple sets section, Marx et al. (47) found that a four times/week training regimen produced significantly greater gains than a three times/week regimen. However, the confounding variables in this study, which were discussed earlier in this paper, call into question the usefulness of the findings.

The studies cited above were all conducted with untrained subjects. As noted above, it has been argued (8,12) that more frequent training will benefit experienced trainees. However, the scientific evidence does not support this claim. McLester et al. (80) examined the effects of a whole-body training program, consisting of nine exercises performed either one or three times/week, on the strength of experienced weight trainers. Subjects had an average of 5.7 years experience in weight training. No significant between-group differences were found in the post-test on eight out of the nine strength measures, leaving McLester et al. to conclude that training once/week is equally as effective as training three times/week.

The only other study to have examined the effects of differing training frequencies on strength in experienced trainees was that of Hoffman et al. (81). This study recruited Division 1 American football players who self-selected a training frequency of three, four, five or six days/week. This lack of randomised allocation of subjects to groups, as well as a great imbalance in group size (for example, there were less than half the number of subjects in the three times/week group than in the five times/week group), calls into question the usefulness of this study. On the basis that the five times/week group was the only group to significantly improve 1 RM bench press (by 3.2 %), Hoffman et al. concluded that the five times/week protocol was best. However, there are some concerns worthy of note here. First, the magnitude of strength increases in this study (i.e. a highest increase of 4.0 % in the bench press and 7.5 % in the squat) appear very low, suggesting either that all the protocols used in this study were rather poorly chosen, or that supervision of the subjects may have been inadequate. Most importantly, all groups improved significantly in nine of the testing variables, contradicting the claim of Hoffman et al. that the five times/week group improved on more variables than the other groups.

Overall, therefore, Jones' claim that optimal training results can be achieved from exercising the whole body twice/week (and, for some muscle groups and some individuals, once/week) is supported by the research literature. Several studies have found no differences between results gained from training once, twice or three times/week (61,62,76,80), one study found training either twice or three times/week to be better than training once/week (78), one study found training twice/week better than training three times/week (77), and another study found training three times/week better than training five times/week (79). The only study that has found high-frequency (i.e. greater than three times/week) training to be more effective is Marx et al. (47), a study loaded with confounding variables. Therefore, it seems reasonable to conclude that for most individuals, training each muscle at the most twice/week (and, in many instances not more than once/week) will provide optimal results.

Speed Of Movement During Exercise

It is commonly suggested by various weight-training authorities (8-12) that to optimally increase muscle strength and (particularly) power, weight-training exercises be performed explosively (i.e. with a relatively fast speed of movement). This, such sources suggest, will lead to greater increases in muscle strength and power than if exercises are performed using a relatively slow, controlled cadence. However, Jones (17,18) advocated a relatively slow lifting speed to reduce momentum and increase muscle tension. He stated (18), "*At the start of the first repetition, muscular contraction should be produced gradually, and should be slowly increased until the start of movement is produced. Once movement at a slow speed has started, the level of effort should remain just high enough to continue slow movement. Do not increase the speed as movement continues*" (p. 44). In practical terms, according to Jones' former Director of Research, Ellington Darden (24), on most exercises such advice translates into duration of at least two seconds for the lifting of the weight and four seconds for the lowering of the weight. Jones (17) argued that such a training style would lead to optimal increases in strength, power and muscle size, and should be coupled with much practice of the specific skill to be performed to optimise sports performance.

A study by Mikesky et al. (82) provided strong support for Jones' viewpoint. Mikesky and colleagues examined the effects of a wrist flexion exercise on the forelimb strength and size of 62 cats. The cats were operantly conditioned to perform the exercise using a food reward, and weights were increased as the cats progressed. When a cat failed to make progress for a certain period of time, the muscles of the forelimbs were removed and weighed. The cats that trained with the heaviest weights showed greater muscle mass increases compared to those training with lighter weights. Also, those using slower lifting speeds showed significantly greater increases in muscle mass than those using faster lifting speeds. Mikesky et al. concluded that slow lifting speeds lead to greater strength increases and hypertrophy than faster lifting speeds.

Although research on humans has not proved as conclusive as the animal research of Mikesky et al., it certainly does not appear to support the idea that faster lifting speeds are more effective for strength development. LaChance and Hortobagyi (83) compared the effects of repetition cadence on the number of push-ups and pull-ups subjects were able to complete. They found that subjects could complete more repetitions when performing fast, self-paced repetitions than when performing two-second concentric and two-second eccentric muscle actions, and that subjects could complete still fewer repetitions when performing two-second concentric and four-second eccentric contractions. Therefore, the difficulty of the exercise decreased as repetition cadence decreased. This suggests that faster repetitions involve less muscle tension, making it difficult to see how a faster speed of movement could be more productive. This view is supported by the findings of Hay et al. (84) who measured joint torque in three males while performing biceps curls. Hay et al. found that with short duration lifts (< 2 s) very little joint torque was required to move the weight through most of the range of motion (ROM), as after the beginning of the movement the weight continued to move under its own momentum. Again, this shows that fast movements do not provide as much muscle tension as slow movements through most of the ROM, suggesting that faster repetitions may not produce optimal strength increases through a muscle's full ROM. This appears to be strongly supported by a study by Westcott et al. (85), in which 147 previously untrained subjects were assigned to either a 'super-slow' condition (4-6 repetitions/set, 10 s concentric contraction, 4 s eccentric) or a 'traditional' (8-12 repetitions/set, 2 s concentric, 1 s isometric and 4 s eccentric) condition. Both groups performed 1 set of 13 exercises 2-3 times/week for 8-10 weeks. The super-slow group increased their strength to a significantly greater degree than the traditional group, suggesting that not only are faster repetitions no more effective, but also that even slower movements than Jones advocated may be best. Better results from slower repetitions were also found by Jones et al. (86), who found significantly greater increases in 1 RM squat resulting from slower repetitions than from faster ones (though precise movement cadence was not reported in this study).

In contrast, Keeler et al. (87) found greater increases in strength on some exercises from the 'traditional' exercise speed noted above than from the 'super-slow' speed, with an average strength gain of 39 % in the traditional group and only 15 % in the super-slow group after 10 weeks of training. However, as the subjects were novices their strength gains from super-slow seem very low. This may be because, in contrast to the Westcott et al. study, all subjects in this study performed 8-12 repetitions/set. Therefore, in this study the different time under load in the two conditions was a major confounding variable. As super-slow repetitions are more difficult than traditional repetitions, requiring lighter resistance, 8-12 repetitions may require the use of a resistance that is too light to stress the muscle sufficiently. Indeed, this is why super-slow advocates (24) often recommend a range of 4-6 repetitions. Thus, alternative interpretations of Keeler et al's findings are that either the use of very light weights, or the employment of a time under load of between 112 s and 168 s, is not an effective strategy for increasing muscle strength. The study design simply does not permit a conclusion regarding the effectiveness of differently paced repetitions.

A number of studies have found no significant difference between slow and fast-paced repetitions in increasing strength development. For example, Berger and Harris (88) compared the effects of fast (1.8 s), intermediate (2.8 s) and slow (6.3 s) repetitions on bench press performance, with one set of the exercise being performed three times per week for 8 weeks by each group. All groups significantly increased strength, with no significant between-group differences. More recently, Young and Bilby (89) compared the effect of slow versus explosive repetitions on performance of barbell squats. Again, both methods significantly increased 1 RM, as well as isometric peak force, vertical jump, thigh circumference and muscle thickness, with no significant between-group differences. Palmieri (90) split subjects into three groups based on repetition cadence (fast cadence, slow cadence and a combination of both) and examined the effects of a 10-week training program, consisting of squats and machine exercises, in each group. The slow cadence group performed the concentric part of each repetition in 2 s or more, the fast cadence group performed it in 0.75 s or less, and the combination group spent the first 6 weeks performing fast cadence repetitions and the last 6 on slow cadence repetitions. Overall, all groups improved significantly and there were no significant between-group differences. Interestingly, however, when the combination group switched to the fast cadence condition they failed to produce any further increases in the dependent measures, 1 RM squat and lower body power.

Palmieri's findings on lower body power are particularly interesting given the insistence by some authorities that "explosive" training exercises are better for improving muscle power than traditional, slow weight training. For example, in a NSCA publication, Cissik (91) claimed, "*If an exercise is performed at slow speeds, then we become stronger at slow speeds. However, there is little transfer to faster speeds. If exercises are performed at faster speeds, then we become stronger at faster speeds*" (p. 3). Similar statements can be found in many exercise physiology textbooks and coaching-related books and internet sites, but, as in the case of Cissik, such claims are always made with no supporting scientific evidence, which is not surprising as these views are simply not supported by the peer-reviewed scientific evidence. For example, Liow and Hopkins (92) investigated the effect of slow and explosive weight training on kayak sprint performance. The two programs differed only by the time it took to undertake the concentric action of the movement (slow – 1.7 seconds and explosive - < 0.85 seconds). Both training types showed an increase in performance (mean sprint time over the 15 meters increased by 3.4 % [slow training] and 2.3 % [explosive training]) although there were no significant between-group differences. Blazevich and Jenkins (93) examined varying movement velocities in hip flexion and extension, knee extension and flexion and the squat. They reported that there were no significant differences in torque measurements for hip extension and flexion, or 1 RM for the squat or sprint performance between the slow and explosive training groups.

In addition, Wilson et al. (94) compared the effects of traditional resistance training (3-6 sets of 6-10 RM squats), plyometric training and explosive training (loaded jump squats), performed twice/week for 10 weeks with experienced trainees. Both the traditional and explosive groups significantly improved peak power on a 6 s cycle test, with no significant between-group difference. Both groups also increased significantly on vertical and counter-movement jump, with the explosive group increasing to a greater degree. However, this is hardly surprising given that the explosive group had been practicing jumping and the traditional group had not. Only the traditional group increased significantly on maximal knee-extension force. In a follow-up study, Wilson et al. (95) compared the effects of traditional weight training (squats and bench presses) with plyometric training (depth jumps and medicine ball throws). The experimenters tested the effects of these programs on 14 variables related to strength and power, and the traditional group increased significantly on seven variables whereas the plyometric group increased only on three. Also, both groups increased significantly on counter-movement jump, with no significant between-group difference. Similar findings were reported by Holcomb et al. (96), who compared the effects of resistance training and plyometric-style training involving various types of depth jump. No significant between-group differences were found in increases in jump height or power performance, and the authors concluded that plyometric training was no more effective for increasing power than traditional resistance training.

Some research even suggests that some methods of explosive training may be less effective than slow weight training for increasing power. Newton and McEvoy (97) compared the effect of slow, controlled resistance training and explosive medicine ball throws in Australian baseball players. Only the resistance-training group significantly increased throwing velocity, and this group also increased 6 RM bench press to a significantly greater degree than either the explosive group or control group. Interestingly, there was no significant difference between these latter two groups.

Possibly the most interesting study to compare the effects of resistance training and plyometric-style (depth jumping) exercises was performed by Clutch et al. (98). In this study, half the subjects were members of a weight training class and the other half were volleyball players. Subjects were divided into four groups: a resistance training only group, a resistance training and depth jumping group, a volleyball playing and resistance training group, and a volleyball playing, resistance training and depth jumping group. All groups significantly increased vertical jump after 16 weeks of training, with the exception of the group that only did resistance training. There were no significant differences among the other three groups. The authors concluded that depth jumping provided no additional benefit to performing resistance training and practicing the specific skills involved in volleyball. Therefore, it appears that the only training necessary to optimise performance of a specific skill is the performance of that skill and separate resistance training.

Jones (18) provided an interesting practical example of the efficacy of slow weight training for those involved in 'explosive' sports. In 1973, an Olympic weightlifting team was formed at DeLand High School, Florida. The team trained with only slow (mostly eccentric-only) weight training. Starting in 1973, and with no previous experience in weightlifting, the team established what is probably a world sporting record: the team was undefeated and untied for seven years, winning over 100 consecutive weightlifting competitions. Clearly, the experience of these weightlifters is very much at odds with the view of Cissek (91) and others that slow weight training is not effective in enhancing in enhancing muscle performance at fast speeds.

Overall, therefore, it appears that Jones' (17,18) recommendation that slow, controlled weight training is all that is necessary to enhance both muscle strength and power is correct. Studies have tended to suggest that either slow training is superior to explosive training in enhancing these factors, or that there is no difference between slow and fast speeds. Despite claims made in some strength training textbooks (8,9) and by some exercise certification organisations (11,12) there is no scientific evidence to support the view that resistance exercise performed at very fast speeds is superior for enhancing any aspect of muscle function.

Not only is 'explosive' weight training unnecessary for increasing muscle power, but also such training poses considerable injury risks. For example, Kulund (99) noted that injuries to the wrist, elbow and shoulder were commonplace when individuals performed fast, Olympic-style lifting. Hall (100) found that fast lifting speeds greatly increased shear forces in the lumbar region. Also explosive lifting can apparently lead to spondylolysis (101,102). For example, Kotani et al. (101) found that 30.7% of a sample of weightlifters, all of who performed explosive lifts, suffered from this problem. Therefore, we contend that as well as being unnecessary to enhance performance, advocating explosive lifting is questionable from an ethical standpoint as such training may cause injury. The NSCA and ACSM guidelines are rather ironic in this respect, given that one of the main benefits of strength training is (or at least should be) a reduction in injury risk (103).

Optimal Repetition Ranges For Increasing Muscular Strength And Endurance

It has been claimed (4,6,8,12) that a low number of repetitions per set (< 6) is best for increasing muscular strength, and a high number of repetitions per set (> 20) is best for increasing muscular endurance. In contrast to this common belief, Jones (18) argued that optimal increases in both strength and endurance would result from performance of a moderate number of repetitions (~8-12). Several studies have examined the effect of different repetition ranges on both strength and endurance, and the results strongly support Jones' hypothesis.

As regards the idea that low repetition sets are better for increasing strength, a study by Chesnut and Docherty (104) illustrates that this is not the case. These authors examined the effects of 10 weeks of 4 RM and 10 RM training programs on elbow flexor and extensor strength and arm circumference and cross-sectional area. Strength and muscle size increased significantly in both groups, with no significant between-group differences. In a study of geriatric females, Pruitt et al. (105) examined the effects of training with 7 repetitions at 80 % 1 RM and 14 repetitions at 40 % 1 RM on various exercises three times per week for a year. Both groups significantly improved on all seven dependent variables (1 RM strength measures), with no significant differences between the groups on six of these. The only significant difference was a greater increase in arm strength in the 14 RM group. Graves et al. (106), in a study of identical twins, found that both a 7-10 RM group and a 15-20 RM group significantly increased quadriceps strength from one set of knee extensions performed twice/week for 10 weeks. Again, however, there was no significant difference between the strength increases achieved by the two groups. Several other studies (107-111) have shown similar results, i.e. no significant difference between strength and/or hypertrophy responses to low and moderate repetition ranges. Despite the claims noted above, no study has demonstrated that very low repetitions are superior to a moderate number of repetitions for increasing strength.

Few studies have examined the claim that higher repetition sets are more effective than lower repetition sets for increasing absolute muscular endurance. Anderson and Kearney (110) examined the effects of three different combinations of sets and repetitions on muscular endurance (measured by the number of bench press repetitions subjects could perform with 27.23 kg). Subjects were divided into low repetition (3 sets of 6-8 RM), medium repetition (2 sets of 30-40 RM) and high repetition (1 set of 100-150 RM) groups, and each subject trained three times/week for nine weeks. No significant between-group differences in increases in muscular endurance were found. Stone and Coulter (111) examined the effects of three training protocols (3x6-8 RM, 2x15-20 RM, and 1x30-40 RM) on the muscular endurance of untrained females, each of whom trained three times/week for nine weeks Again, no significant between-group differences in muscular endurance increases were found.

The weight of scientific evidence, therefore, does not support the idea that different numbers of repetitions have differential effects on muscular strength and endurance. A low to moderate number of repetitions has been shown to produce optimal increases in muscular strength and size, with no specific repetition range proving superior. Increases in muscular strength are accompanied by increases in absolute muscular endurance, with no advantage accruing in this regard from the use of a high number of repetitions. Given these research findings, and also given that performing a very low number of repetitions may lead to a greater injury risk due to the heavier weight and thus greater forces imposed on muscle, joints and connective tissues, it appears that Jones' recommendation of a moderate repetition range (~8-12) is efficacious and prudent.

CONCLUSIONS

In his writings over a 30-year period, Arthur Jones provided a series of weight training guidelines that have stood the test of time and have been strongly supported by scientific research. Specifically, Jones' recommendations to perform one set of each exercise to muscular failure, to train each muscle group no more than twice/week (and in most cases once/week), to perform weight training exercises with a relatively slow, controlled cadence and to perform a moderate range of repetitions to increase muscular strength, size, endurance and power, have all been validated by a great deal of peer-reviewed research. The same cannot be said of the high-volume, explosive training protocols that are currently in vogue amongst many exercise physiologists and strength-training professionals.

We note that previous articles advocating evidence-based training protocols (35,36) have met with the objection that NSCA-style, high-volume training is much more popular than Jones' approach among the athletic fraternity (21,112). We anticipate similar reactions to this paper, and therefore would like to make a couple of points regarding the argument that the popularity of the training methods advocated by the NSCA and others indicate that such methods are more efficacious than those of Jones and colleagues. Essentially, such individuals have argued that because the majority of athletes train in a particular manner, this must be the best way to train. This begs the question, why bother to perform scientific research at all? If such an argument is carried to its logical conclusion, rather than performing research to determine optimal training protocols, the time and money would be better spent conducting a poll of trainees to determine which method is most popular. This would then be the one that scientists should advocate. We contend that such individuals resort to such arguments purely because the scientific research does not support their position.

It is also interesting to note that Jones has had a major influence on the training methods of many accomplished individual athletes, sports teams and organisations, though these are still in the minority. For example, organisations such as the United States Military Academy, the United States Naval Academy, the sport teams at Princeton University, Penn State University, Rutgers University and many other educational establishments, and many teams in the US National Football League, have used Jones' methods extensively. The list of bodybuilders who have been heavily influenced by Jones reads like a Who's Who of the sport. Dorian Yates (six times Mr Olympia), Sergio Oliva (twice Mr Olympia), Mike Mentzer (Mr Universe), Ray Mentzer (Mr America) and Casey Viator (Mr America) are among the professional bodybuilders who have cited Jones as a major influence on their training. Thus, despite the efforts of the NSCA (11), ACSM (12) and others (8,44,45) to discredit Jones' ideas, many athletes, from novice to collegiate and professional level, have applied Jones' principles with considerable success. We strongly recommend that other athletes follow their example and apply Jones' training advice. Individuals should also take the time to examine the relevant scientific research at first hand rather than relying on the interpretations and recommendations of prominent exercise physiologists which are based on personal bias rather than scientific evidence. Specifically, we would strongly dissuade athletes and coaches from following the recommendations of the ACSM and NSCA, and instead suggest that they follow the research-based guidelines that are presented in Table 1, together with references to supporting research.

Table 1. Summary of research-based strength training recommendations.

Variable	*Recommendation*	*Rationale*	*Exceptions*	*References**	*Supporting Research*
Number of sets/exercise	One set to muscular failure	All well-controlled studies show no advantage in performing multiple sets	None	15,16,18, 19, 20	28,29,30,34,56, 57,58,59,60
Frequency of training/muscle	Once/week for most muscles	Great majority of studies show training each muscle once/week to produce optimal improvements	The muscles that rotate the torso appear to benefit more from training twice/week	20	32,61,62,76, 78, 80
Speed of movement	Slow, non-explosive	Explosive repetitions involve more momentum and less muscle force, do not produce greater increases in power and may involve greater injury risk	None	17,18,24	82,83,84,85,86, 88,89,90,92,93, 94,95,96,97, 99, 100, 101, 102
Number of repetitions/set	~8-12	Varying the number of repetitions higher or lower does not produce differing effects on strength or muscular endurance	None	18	104,105,106, 107,108, 109,110,111

*Original references published by Arthur Jones
The reference numbers in the Table refer to the corresponding numbers in this paper's reference list.

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The ACSM Challenge of a 'Gold Standard'

To this day, in the USA at least, the American Council on Sport Medicine (ACSM) is considered the 'gold standard,' as being 'the' exercise authority. Often when a position statement is quoted, on some aspect of fitness, it comes from a book or paper published by the ACSM.

During the 1990s, Dr. Michael Pollock was President of the ACSM, a highly objective individual who worked with the University of Florida, and with Arthur Jones and MedX. Based on the industry's vast research, he helped to established the position statement of the ACSM to suggest that there is no benefit to performing multiple sets of an exercise (although a muscle may require more than one exercise), that exercise 1-2 times per week and per muscle was sufficient, that periodization did not prove any more effective than a standard protocol, and that intensity of effort was an important, governing factor in exercise productivity, i.e., quality vs. quantity.

Shortly after Dr. Pollock's unexpected demise in the late 1990s, individuals affiliated with other organizations, including the National Strength and Conditioning Association (NSCA), took control of the ACSM and altered its position statement to promote multiple set training (upward of 8 sets per exercise), periodization, and workouts that lasted at least one hour and often more, several times per week. At that time, the ACSM also provided 'evidence' by way of research references to support its position. However, a group of dedicated individuals in the pursuit of the truth challenged the ACSM's stance, which can be read by reviewing the 60-page meta-analysis at the end of this section, beginning on page 180.

Since the release of that document, in June 2004, no one from the ACSM would go on record to defend its position or the challenges brought forth in 'fudging' the facts of what the research actually supports. Then, in June 2005, the ACSM released *a revised position on exercise prescription*, which closely mirrors its original recommendations under the auspices of Dr. Michael Pollock and which supports the direction of high-intensity (and full-body) training. This 'revised' position is presented on the following two pages.

ACSM Now Endorses Simple Training Programs for Experienced Trainees*

In a *shift* from its prior position stand statement about progressive resistance training for experienced trainees (1), the American College of Sports Medicine (ACSM) in its 7th edition of its *Guidelines for Exercise Testing and Prescription* (2) now endorses much simpler training programs as effective for both beginners and experienced trainees.

A majority of the recommendations from the Guidelines book were presented at the recent ACSM national convention without disagreement.

1. Perceived effort is a good measure of intensity. Rather than focusing on protocols that use different percentages of 1 RM, focus on perceived effort. Using different percentages of 1 RM is not a good way to prescribe exercise programs. This is because across individuals, and different muscle groups, and different exercises, the same percentage of a 1 RM can yield a different number of repetitions. Such differences can exist within an individual. This means that for some people and for any exercise an individual performs, the prescription can be too hard or too easy, rendering it ineffective.
2. Different repetitions and resistance can yield the same degree of effort when the *maximum repetitions are performed* in a set. This means that a wide range of repetitions for a set can be *equally effective*. For example, a very high degree of effort and intensity can be reached in a set where you perform six repetitions in good form with a heavy resistance and 'fail' on an attempt at a seventh repetition or where you perform 12 repetitions with a more moderate weight and 'fail' on an attempt at a 13th repetition. In either case, the maximum recruitment of muscle fiber motor units would have occurred. You can choose to train with any number of repetitions with an effective set taking between about 30 seconds and 90 seconds.
3. There is no evidence that there is a separate way to train for strength or endurance. As you become stronger, you will increase your absolute muscular endurance. For example, if through training, you increase your strength in a movement from 60 lbs to 85 lbs, you may increase the number of repetitions you can perform with 40 lbs from 12 to 20. No special training is required to increase endurance. For each person and for each exercise and muscle group, relative muscular endurance is stable and appears genetically based. For example, a beginner's 1 RM on an exercise may be 100 lbs and the trainee can perform 8 repetitions with 80 lbs (80%). Two years later, the trainee can do a 1 RM with 200 lbs and perform 8 repetitions with 160 lbs (80%). Relative endurance using a percent of 1 RM hasn't changed and evidence indicates that it will not change. Protocols assuming that the relationship can be changed are not based on scientific research.
4. Based on raising a resistance in about 3 seconds and lowering the resistance in 3 seconds, performing several to 15 repetitions can be effectively used. If longer duration repetitions are performed such as using a 5, 5 (10 seconds for 1 repetition) then several to 8 to 10 repetitions can be used.
5. Increasing bone mineral density may depend upon using somewhat lower repetitions such as 6-8 and therefore training with somewhat greater resistance. A variety of exercises can be used because the effect of resistance training on bone mineral density is site specific.
6. To increase strength, training has to produce an overload beyond a minimal threshold. Maximum effort produces maximum intensity and the greatest stimulus but the maximum stimulus may not produce any greater adaptation than a somewhat submaximal effort if there is some marginal overload. This means you should focus on progression while using great form and not an absolute maximum effort where form may be compromised.
7. Train through as complete a range of motion that is comfortable for you.

* Extracted from the web site http://ageless-athletes.com

8. Assuming all the other variables are kept constant, the intensity of training can be increased by increasing the weight, number of repetitions, and *by reducing momentum through increasing the repetition's duration*. Muscular tension for an exercise may be maintained and intensity increased by not 'locking-out' on multiple joint exercises such as squats and bench press.
9. There is no evidence that any one exercise is better than any other exercise for a specific muscle group. There is no evidence that performing an exercise a specific way such as on a stability ball produces better outcomes for strength or endurance than if the exercise is performed in another way. The exercises are simply different.
10. A variety of exercises can be used for each muscle group and can perhaps provide some physiological and psychological benefits beyond consistently performing the same exercise for a muscle group. However, a variety of exercises for each muscle group need not be performed in one training session but rather across training sessions.
11. While a few researchers have shown better outcomes for strength and muscular hypertrophy with multiple set protocols, the *overall evidence does not support the performance of multiple sets* of each exercise or higher volume training.
12. A guideline is to take about 3 seconds to raise the resistance and about 3 seconds to lower the resistance using a full range of motion for each repetition. Longer duration repetitions may decrease momentum and increase intensity.
13. There is not any consistent evidence that the stimulus (repetition performance, number, duration, volume of training) for experienced trainees needs to be different than for beginning trainees. Therefore, there is little or no basis for special 'advanced' routines promoted by some organizations, websites, and magazines.
14. A program for any trainee can consist of eight to 10 exercises performed two to three days per week. Different exercises for each muscle group could be varied across workouts. For example, a squat can be used for the thighs in the first workout in a week and the leg press can be used in the second workout.
15. One set per exercise performed to volitional fatigue can be used with 5-6 to 15 repetitions in a set if a 3,3 duration repetition duration is employed.
16. Training should be on two or three nonconsecutive days in the week.

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A CRITICAL ANALYSIS OF THE ACSM POSITION STAND ON RESISTANCE TRAINING: INSUFFICIENT EVIDENCE TO SUPPORT RECOMMENDED TRAINING PROTOCOLS

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ABSTRACT

A CRITICAL ANALYSIS OF THE ACSM POSITION STAND ON RESISTANCE TRAINING: INSUFFICIENT EVIDENCE TO SUPPORT RECOMMENDED TRAINING PROTOCOLS. **Ralph N. Carpinelli, Robert M. Otto, Richard A. Winett**. **JEP**online 2004;7(3):1-60. In February 2002, the American College of Sports Medicine (ACSM) published a Position Stand entitled Progression Models in Resistance Training for Healthy Adults. The ACSM claims that the programmed manipulation of resistance-training protocols such as the training modality, repetition duration, range of repetitions, number of sets, and frequency of training will differentially affect specific physiological adaptations such as muscular strength, hypertrophy, power, and endurance. The ACSM also asserts that for progression in healthy adults, the programs for intermediate, advanced, and elite trainees must be different from those prescribed for novices. An objective evaluation of the resistance-training studies shows that these claims are primarily unsubstantiated. In fact, the preponderance of resistance-training studies suggest that simple, low-volume, time-efficient, resistance training is just as effective for increasing muscular strength, hypertrophy, power, and endurance—regardless of training experience—as are the complex, high-volume, time-consuming protocols that are recommended in the Position Stand. This document examines the basis for many of the claims in the Position Stand and provides an objective review of the resistance training literature.

Key Words**:** Strength, power, hypertrophy, muscular endurance

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INTRODUCTION

The American College of Sports Medicine (ACSM) published a Position Stand (1) entitled *Progression Models in Resistance Training for Healthy Adults,* which attempts to augment the ACSM's previous Position Stand (2) entitled *The Recommended Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory and Muscular Fitness, and Flexibility in Healthy Adults*. The most recent Position Stand claims that the ACSM's previous resistance-training recommendation to perform 1 set of 8-12 repetitions 2-3 times/week for all the major muscle groups is effective for only previously untrained (*novice)* individuals, and that it did not include guidelines for those who wish to improve muscular strength, hypertrophy, power, and endurance beyond the beginning programs (p. 365).

The Position Stand states that its purpose is to provide guidelines for progression in *intermediate* trainees, who are defined in the Position Stand as those with approximately six months of consistent resistance training, for *advanced* trainees with years of resistance training, and for *elite* athletes who are highly trained and compete at the highest levels (p. 366).

Given the way that the ACSM has defined and categorized their target populations (intermediate, advanced, and elite trainees), the reader should expect that the Position Stand would first cite evidence to support their assumption that the target populations require training programs different from beginning programs, and then present supporting evidence (peer-reviewed resistance-training studies) for recommendations that are drawn exclusively from those specific demographics. Neither obligation is fulfilled in the Position Stand, thereby rendering the majority of claims in the Position Stand unsubstantiated.

The preponderance of published resistance-training research has used previously untrained subjects. Consequently, most of the studies cited in the Position Stand and in this document involved subjects with little or no resistance training experience (novices). Although the rate of progression tends to be greater in novices than in intermediate and advanced trainees, there is very little evidence to suggest that the resistance-training programs recommended for increasing muscular strength, hypertrophy, power, and endurance in novice trainees need to be different for intermediate and advanced trainees.

Because many resistance-training reviews and books may be inundated with misinterpretations of legitimate resistance training studies, and often contain unsubstantiated opinions, the only acceptable sources of supporting evidence are peer-reviewed resistance-training studies (primary sources). Therefore, secondary sources such as reviews and books are not acceptable as evidence, and consequently they are not discussed in this document.

Contrary to the ACSM's claim that Positions Stands are based on solid research and scientific data (3), we specifically demonstrate how the Position Stand based its claims and recommendations on selective reporting or misinterpretation of studies, and that the Position Stand represents merely the unsubstantiated opinions of its authors and the ACSM.

The entire burden of proof is on the authors of the Position Stand and the ACSM to support their claims and recommendations with resistance-training studies, and that proof must be based entirely on the evidence that was available prior to and throughout the preparation of their document. Because we do not claim that one resistance-training protocol is superior to another, it is not our responsibility to cite studies. However, in order to reveal the selective reporting of studies in the Position Stand, we cite a number of resistance-training studies that do not support the primary claim or recommendation in the Position Stand. All the studies we cite were in print and available to the authors of the Position Stand prior to its publication. Thus, our objective analysis of the Position Stand also relies exclusively on resistance training studies that were available prior to the publication of the Position Stand.

We address all the components of a resistance training program, which include the selection of a training modality (free weights and machines), repetition duration (speed of movement), range of repetitions, number of sets, rest between sets and exercises, types of muscle actions, and frequency of training. Because the ACSM and the authors of the Position Stand apparently believe that muscular endurance, power, and hypertrophy are differentially affected by various training protocols and that specific adaptations are affected by so-called *periodization*, they created separate categories for these topics. Therefore, we also address each of these issues separately.

Our document concludes with remarkably simple recommendations for resistance training, which are based on the preponderance of scientific evidence.

FREE WEIGHTS AND MACHINES

The Position Stand claims that multiple-joint exercises such as the bench press and squat are generally regarded as most effective for increasing overall muscular strength because they enable a greater magnitude of weight to be lifted (p. 368). Only a review by Stone et al. (4) is cited in an attempt to support that claim.

The Position Stand claims that resistance exercise machines are safer to use, easier to learn, allow the performance of some exercises that may be difficult with free weights, help stabilize the body, and focus on the activation of specific muscles (p. 368). The only reference cited is an article by Foran (5), which is a brief opinion about machines that states nothing related to—and therefore does not support—the opinions expressed in the Position Stand.

The Position Stand claims that resistance training with free weights results in a pattern of intra- and inter-muscular coordination that mimics the movement requirements of a specific task and that emphasis should be placed on free-weight exercises for advanced resistance training, with machine exercises used to complement the program (p. 368). There is no reference cited to support either opinion.

Only a few studies (6-8) have compared the effects of free weights and machines on muscular strength. Boyer (6) randomly assigned 60 previously untrained females (19-37 years) to one of three resistance-training programs. All subjects performed 3 x 10 RM (i.e., 3 sets of 10 repetitions where RM denotes a maximal effort on the last repetition of a set) wk 1-3, 3 x 6 RM wk 4-6, and 3 x 8 RM wk 7-12 on two lower-body and five upper-body exercises 3x/wk for 12 weeks. They exercised similar muscle groups using free weights, Nautilus® machines, or Soloflex® machines, which utilize rubber weight straps for resistance. There was a significant pre- to post-training decrease in thigh (16.6, 14.5 and 14.5 %), arm (15.8, 8.9 and 17.1 %) and iliac (4.2, 7.3 and 9.6 %) skin-folds, and percent body fat (9.6, 6.2 and 9.6 %) for the free-weight, Nautilus® and Soloflex® groups, respectively, with no significant difference between the groups for any anthropometric variable. The free-weight group showed significantly greater gains than the Nautilus® group when tested on the equipment used for training: 1 RM bench press (24.5 and 15.3 %), behind-the-neck press (22.3 and 10.9 %), and leg sled (15.5 and 11.2 %), for free-weight and Nautilus® groups, respectively. The Nautilus® group showed significantly greater gains than the free-weight group when tested on the Nautilus® machines: bench press (23.3 and 47.2 %), lateral raise (19.4 and 46.8 %), and leg press (17.1 and 28.2 %), for the free-weight and Nautilus® groups, respectively. Overall, the average strength gain in the free-weight group was 20.4 % (Nautilus and free-weight equipment combined), while the Nautilus® group increased 26.6 % (Nautilus and free-weight equipment combined). Interestingly, the Soloflex® group significantly increased strength by 29.5 % when tested on the Soloflex® machine and 15.1 % when tested on the other modalities. Boyer (6) concluded that although the strength gains were significantly greater when each group was tested on their training modality, the programs produced comparable changes in muscular strength and body composition.

Sanders (7) randomly assigned 22 college students to a free-weight (bench press and behind-the-neck seated press) or Nautilus® (chest press and shoulder press machines) training group. All subjects performed 3 x 6 RM 3x/wk for five weeks. They were tested pre- and post-training for 3-minute bouts of rhythmic isometric exercise (maximal muscle actions every other second) for the elbow extensors at 90° and shoulder flexors at 135°. Initial and final strength levels were measured by using the average of three successive muscle actions at each 15-second time interval. A strength decrement during each test was obtained by subtracting the final strength from the initial strength. Results revealed that elbow extensor strength significantly increased in the free-weight (~22 %) and Nautilus® groups (~24 %). Shoulder flexor strength significantly increased following free weight training (~12 %) and Nautilus® training (~13 %). There was no significant difference between the free weight and Nautilus® groups for initial strength, final strength, or strength decrement. Sanders (7) concluded that free weights and Nautilus® machines were equally effective for developing muscular strength and endurance.

Silvester et al. (8) reported the results of two experiments comparing free weights and machines. In experiment #1, 60 previously untrained college-age males were randomly assigned to one of three groups who performed 1 x 4-16 RM for the lower-body exercises using a Nautilus® machine, Universal® machine (2 x 7-15), or free-weight squats (3 x 6). The intensity for the Universal® and free-weight groups was not specified. The

Nautilus® and free-weight groups completed each repetition in three seconds, while the Universal® group did not exceed two seconds for each repetition. The Universal® and free-weight groups trained 3x/wk for 11 weeks, while the Nautilus® group trained 3x/wk for the first six weeks and 2x/wk for the last five weeks. There was a significant increase in vertical jump height (0.2, 1.0, and 1.3 %, for Nautilus®, Universal®, and free-weight groups, respectively). Silvester et al. (8) noted that it appeared that the Universal® and free-weight groups improved to a greater extent than the Nautilus® group, with no significant difference between the Universal® and free-weight groups. However, later in their Discussion they state that the increases in vertical jump were equal (p. 32). There was a significant increase in lower-body strength (8.6, 9.7, and 12.5 %, for Nautilus®, Universal®, and free-weight groups, respectively), with no significant difference among the groups. Different numbers of sets and repetitions, intensity, repetition duration, frequency of training, and types of equipment did not result in significantly different gains in strength.

In experiment #2, Silvester et al. (8) randomly assigned 48 previously untrained college-age males to one of four groups who performed barbell curls for either one set or three sets of six repetitions with 80 % 1 RM, or one set or three sets of 10-12 RM Nautilus® machine curls 3x/wk for eight weeks. The four groups significantly increased elbow-flexion strength at four angles (70, 90, 135, and 180°) after training with one set of barbell curls (23 %), three sets of barbell curls (30 %), one set of Nautilus® machine curls (25 %) or three sets of machine curls (19 %). There was no significant difference in strength gains among the groups at any angle. Silvester et al. (8) concluded that one set is just as effective as three sets, and that it does not appear to matter which modality of resistance training (free weights or machines) is chosen.

In summary, there is no scientific evidence cited in the Position Stand to support the superiority of free weights or machines for developing muscular strength, hypertrophy, power, or endurance (Table 1). Either training modality or a combination of modalities appears to be effective.

Table 1 provides a summary of the studies in this section and their relative support, or lack of support, for the Position Stand. The order of presentation in Table 1 and the level of support for each study follow the descriptions in the narrative. Summary tables using the same format are provided in subsequent sections.

Table 1. Summary of Research Comparing Free Weights and Machines.

Reference	Rating
Boyer (6)	*
Sanders (7)	*
Silvester et al. (8)	↓

↑ Studies cited in the Position Stand that actually support the primary claim or recommendation.

? Studies cited in the Position Stand that support the primary claim or recommendation but contain serious flaws in the methodology or data.

↓ Studies cited in the Position Stand that fail to support the primary claim or recommendation.

* Studies not cited in the Position Stand that repudiate the primary claim or recommendation.

REPETITION DURATION

The Position Stand often incorrectly refers to the *duration* of a repetition or muscle action as *velocity* of muscle action (p. 368). For example, a 1 s concentric muscle action coupled with a 1 s eccentric muscle action is actually a description of a shorter duration repetition, while a 10-second concentric muscle action and 4 s eccentric muscle action is a longer duration repetition. Seconds do not describe the velocity of muscle action. Speed of movement may be expressed in °/s or radians/s for rotational motion, and cm/s for linear movement.

The Position Stand claims that muscle actions that are less than 1 to 2 s duration have been shown to be more effective than longer durations for increasing the rate of strength gain (p. 369), and they cite a study by Hay et al. (9). Hay et al. (9) compared the resultant joint torque in three resistance-trained males (~33 years). The subjects used different loads and rates of lifting while performing seated curls with a barbell as well as with a curling device on a machine. Hay et al. (9) noted that when the duration of the lift was less than two seconds, very little torque was required to maintain momentum during the latter half of the lift. That is, faster lifting made the exercise easier (less intense). Antithetically, and without any rationale, Hay et al. (9) expressed their opinion that for a given load, a faster rate of lifting (shorter duration) is likely to yield a slightly better rate of strength development than slower rates of lifting (longer duration). However, because this was not a training study, there is no evidence to support the opinion of Hay et al. (9) or the claim in the Position Stand.

In support of shorter repetition durations, the Position Stand cites a study by Keeler et al. (10) who randomly assigned 14 previously untrained females (~33 years) to either a *traditional* (2 s concentric/4 s eccentric) or *super-slow* (10 s concentric/5 s eccentric) resistance-training protocol. A stopwatch was used to monitor repetition duration. All subjects performed 1 set of 8-12 repetitions to muscular fatigue for each of eight exercises 3x/wk for 10 weeks. The traditional group initiated the program with 80 % 1 RM, while the super-slow group used 50 % 1 RM. Both groups significantly increased 1 RM for all eight exercises, with the traditional group showing significantly greater gains in five out of the eight individual exercises and a significantly greater overall increase in strength (39 %) compared with the super-slow group (15 %). There was no significant change in body mass, percent fat, lean body mass or body-mass index in either group.

The results reported by Keeler et al. (10) suggest that the 2 s/4 s repetition duration produced significantly greater gains in some strength measures compared with a 10 s/5 s protocol. However, the small strength gains for the super-slow group (e.g., ~7 % leg press and ~11 % bench press) in previously untrained females after 10 weeks of resistance training suggest that the protocol selected for the super-slow group (8-12 repetitions with 50 % 1RM) was remarkably ineffective.

Westcott et al. (11) reported the results of two studies that were conducted in a recreational training center. Although the 147 previously untrained males and females (25-82 years) were not randomly assigned, they chose a specific time to train based on their schedule without knowing whether the *traditional* (shorter repetition duration) or *super-slow* protocol (longer repetition duration) was assigned to a specific group. The traditional group performed 8-12 repetitions using a 2 s concentric, 1 s isometric, and 4 s eccentric duration, while the super-slow group performed 4-6 repetitions with 10 s concentric and 4 s eccentric muscle actions. Intensity was not described for either group. Strength was assessed using a 5 RM in the super-slow group and 10 RM in the traditional group. Westcott et al. (11) claimed that the time under load (~70 s) was similar for both groups during testing and training. Both groups performed one set for each of 13 exercises 2-3x/wk for 8-10 weeks. In the first study, the super-slow group showed significantly greater strength gains (59.1 %) for the 13 exercises compared with the traditional group (39.0 %). In the second study (only the results of the chest-press exercise were reported), the super-slow group also showed a significantly greater strength gain (43.6 %) compared with the traditional group (26.8 %). Westcott et al. (11) did not use a metronome or any other timing device to measure repetition duration (the independent variable) during either the testing or the training in either study. Therefore, because there was no control for the independent variable, any conclusion from this study (11) relative to repetition duration should, at best, be regarded as questionable.

In summary, neither of these studies by Keeler et al. (10) or Westcott et al. (11) provides sufficient evidence to support the advantage of one repetition duration over another.

The Position Stand claims that compared with longer repetition durations, moderate (1-2 s concentric/1-2 s eccentric) and shorter (<1 s concentric/1 s eccentric) durations have been shown to be more effective for enhanced muscular performance (p. 369). Studies by LaChance and Hortobagyi (12) and Morrissey et al. (13) are cited. LaChance and Hortobagyi (12) reported the acute effects of different repetition durations (*fast self-paced*, 2 s concentric/2 s eccentric, and 2 s concentric/4 s eccentric) for push-up and pull-up exercises in 75 moderately trained college-age males. The exercise was terminated when a subject was unable to complete a full range of motion or maintain prescribed duration. The self-paced duration resulted in a greater number of repetitions performed, and greater concentric work and power than the longer repetition durations for both pull-up and push-up exercises. The number of push-ups (sixty-four) and pull-ups (eleven) in the self-paced trial was significantly greater than the 2 s/2 s protocol (thirty-eight and seven), and the 2 s/4 s protocol (twenty-six and six), push-ups and pull-ups, respectively. All the exercises were performed with the same resistance (an estimated percent of the subject's body mass). Therefore, the results suggest that the longer duration repetitions were harder (greater intensity) than the shorter, self-paced duration. Because this was not a training study (12), the opinion stated in the Position Stand that shorter duration repetitions are more productive than longer durations is relevant only to the acute demonstration of a specific muscular performance, with no evidence that the specific performance will transfer to other demonstrations of muscular performance, and more importantly, no evidence to suggest that shorter repetition durations will stimulate superior adaptations for enhancing muscular performance.

Morrissey et al. (13) randomly assigned 24 previously untrained females (~24 years) to perform six sets of free-weight squats (50 % 8 RM set 1, 75 % 8 RM sets 2-3, 8 RM sets 4-6) 3x/wk for seven weeks. The longer-duration group used a 2 s concentric/2 s eccentric repetition duration (2 s/2 s) and the shorter-duration group used 1 s concentric/1 s eccentric (1 s/1 s). A custom made device was used to cue the subjects to the appropriate repetition duration. There was a significant increase in horizontal long-jump distance in both the 1 s/1 s (44 %) and 2 s/2 s (31 %) groups, but Morrissey et al. (13) did not state whether the difference between groups was significant. Improvement in vertical jump was significant only in the 1 s/1 s group (12 %), although the authors noted that the percent change in the 2 s/2 s group (20 %) exceeded that of the 1 s/1 s group. The pre- to post-training increases in concentric work on an isokinetic dynamometer were significant for all test velocities in the shorter-duration group and were not significant for the longer-duration group. However, Morrissey et al. (13) specifically noted that both groups significantly improved in all the numerous variables that have practical significance, including the 1 RM slow squat (26 and 31 %), 1 RM fast squat (30 and 26 %), vertical jump peak force rate (59 and 62 %), peak power (10 and 9 %), average power (35 and 30 %), long jump peak force rate (77 and 73 %), peak power (17 and 22 %), average power (27 and 37 %), and knee extension isometric peak torque (13 and 16 %), for the 2 s/2 s and 1 s/1 s groups, respectively. There was no significant difference between groups for any of these variables. Morrissey et al. (13) concluded that the squat tests did not support the concept of a specificity of velocity (repetition duration) for resistance training.

The Position Stand claims that studies have shown that using shorter repetition durations with moderately high resistance (not defined) are more effective for advanced training than longer durations (p. 369). However, the references cited (14-15) do not support this opinion. Jones et al. (14) randomly assigned 30 males (~20 years), who were Division I baseball players with approximately three years resistance training experience, to a high-resistance or low-resistance group. The high-resistance group performed 3-10 repetitions with 70-90 % 1 RM and the low-resistance group used 40-60 % 1 RM for 5-15 repetitions. All subjects performed three full range-of-motion sets and one partial range of motion set, with two minutes rest between sets for each of four exercises (parallel squat, dead lifts, lunges, and partial squats) 2x/wk for 10 weeks. All the trainees in both groups attempted to move the resistance as rapidly as possible during the concentric phase of each repetition. Neither repetition duration nor velocity of movement was reported for any of the four exercises. Subjects were tested for maximal performance: peak power, force, and velocity in the set angle jump (140°), countermovement jumps with 30 and 50 % 1 RM, and depth jumps at 27 cm. There was no significant difference between the high-resistance (70-90 % 1 RM) and low-resistance (40-60 % 1 RM) groups for any of the 12 performance outcomes. Jones et al. (14) assessed strength using a 1 RM parallel squat. The gain in the high-resistance group (presumably the longer repetition duration) was significantly greater than the low-resistance (shorter duration) group (16.3 and 11.5 %, respectively). Jones et al. (14) stated two times in their Abstract and eight times in their Discussion and Practical Application sections that the *trends* in their data are supportive of a specificity of training, which obviously conflicts with the results of their own statistical analysis. Thus, the actual results reported by Jones et al. (14) contradict the claim in the Position Stand.

Moss et al. (15) assigned 31 well-trained (not defined) males (~23 years) to one of three groups that performed unilateral elbow flexion exercise 3x/wk for nine weeks (3 sets wk 1, 4 sets wk 2-5, and 5 sets wk 6-9). The groups performed two, seven or 10 repetitions per set using 90, 35 or 15 % 1 RM (groups G90, G35 and G15, respectively). Moss et al. (15) attempted to make the total contractile time similar for the three groups, which was reported as 3.5 s in each set of repetitions. However, they did not report repetition duration or angular velocity. All subjects were encouraged to perform each lift as fast as possible. As measured by computerized tomography, mean cross-sectional area of the elbow flexors showed a small significant increase (2.8 %) in G35. G90 and G35 showed a significant increase in power at all loads (2.5 kg, 15, 25, 35, 50, 70, and 90 % of pre-training 1 RM). There was no significant difference in power between G90 and G35 at any load. Angular velocity significantly increased at all loads, with no significant difference between G90 and G35. There was a significant increase in 1 RM in G90 (15.2 %), G35 (10.1 %), and G15 (6.6 %), with no significant difference between G90 (presumably the longer repetition duration) and G35 (presumably a shorter repetition duration). The results reported by Moss et al. (15) do not support the claim in the Position Stand.

In summary, the studies by Jones et al. (14) and Moss et al. (15) render the claim in the Position Stand unsubstantiated.

Three studies, involving previously untrained participants that compared repetition durations using free weights (16-17) and free weights and machines (18), were not cited in the Position Stand. Berger and Harris (16) arbitrarily divided 69 male college students into three resistance training groups who performed one set of the free-weight bench-press exercise 3x/wk for eight weeks. The shortest-duration group executed an 18-20 RM at a duration of ~1.3 s/rep, the intermediate-duration group used an 8-10 RM at ~2.8 s/rep, and the longest-duration group performed four repetitions with an 18-20 RM load for a duration of ~6.3 s/rep. Total time for the set was similar for the three groups (25 s). All the subjects performed the sets with a maximal effort for their specific repetition duration. There was a significant increase in 1 RM bench press in the shortest (15.2 %), intermediate (17.7 %), and longest duration (17.7 %) groups, with no significant difference among the groups. Absolute muscular endurance (with 50 % initial 1 RM) significantly increased in the three groups (30.3, 27.5, and 38.2 %, respectively), with no significant difference among the groups. Berger and Harris (16) concluded that the three repetition durations were equally effective for increasing muscular strength and endurance.

Young and Bilby (17) reported the results of resistance training with the free weight barbell squat. Eighteen males (19-23 years) were randomly assigned to one of two experimental groups: one group exploded on the concentric phase of the repetition (shorter-duration group), while the other group performed the concentric portion in what the authors described as a slow and controlled manner to minimize acceleration (longer-duration group). All subjects followed a similar training protocol of four sets of 8-12 RM 3x/wk for 7½ weeks. Both groups showed a significant improvement on maximal rate of force development (68.7 and 23.5%), vertical jump (4.7 and 9.3 %), absolute (21.0 and 22.5 %) and relative (19.5 and 20.4 %) 1 RM, absolute (21.0 and 22.5 %) and relative (19.5 and 20.4 %) isometric peak force, middle (2.1 and 2.2 %) and distal (5.0 and 4.4 %) thigh circumference, vastus intermedialis (24.4 and 21.0 %) and rectus femoris (1.4 and 1.5 %) thickness, and body mass (1.2 and 1.9 %), for shorter-duration and longer-duration groups, respectively. There was no significant difference between groups for any of the measured variables.

Palmieri (18) randomly assigned 54 previously untrained subjects (18-23 years) to one of three training groups: longer-duration, shorter duration, or a combination of longer and shorter repetition durations. All the groups trained the lower body 3x/wk using barbell squats and three machine exercises. For the free-weight squats, all subjects followed a multiple-set program that varied the number of sets, repetitions, and percent 1 RM (2-3 sets of 1-10 repetitions at 53-97 % 1 RM) throughout the 10-week study. Subjects in the shorter-duration group performed the concentric phase of the free-weight squat in three-quarters of a second or less, while those in the longer-duration group executed the concentric portion in two seconds or more. The combination group followed the longer-duration protocol for six weeks and then switched to the shorter-duration protocol for the remaining four weeks. All subjects used a 4 s duration for the eccentric phase of each repetition. Palmieri (18) attempted to estimate lower-body *power* (functional performance) by using the subject's vertical jump height and body mass. The three groups showed a significant increase in lower-body functional performance (3.7, 3.8 and 3.2 %) and 1 RM squat (25, 20, and 20 %, longer-duration, shorter-duration, and combination groups, respectively), with no significant difference among the groups for either measure. When the combination group switched from the longer-duration protocol to the shorter-duration protocol, there was no increase in either 1 RM squat or lower-body functional performance for the remaining four weeks. Palmieri (18) concluded that training with longer, shorter or combination of longer and shorter repetition durations will produce similar gains in lower-body strength and functional performance.

The Position Stand recommends that advanced trainees use *unintentionally slow* to *fast training velocities* in order to maximize strength (p. 369). There is no evidence cited to support this recommendation.

In summary, there is very little evidence to support the superiority of any specific repetition duration for developing muscular strength, hypertrophy, power, or endurance (Table 2).

Table 2. Summary of Research Comparing Repetition Duration.

Reference	Rating
Berger & Harris (16)	*
Hay et al. (9)	↓
Jones et al. (14)	↓
Keeler et al. (10)	↑
LaChance & Hortobagyi (12)	↓
Morrissey et al. (13)	↓
Moss et al. (15)	↓
Palmieri (18)	*
Westcott et al. (11)	?
Young & Bilby (17)	*

↑ Studies cited in the Position Stand that actually support the primary claim or recommendation.
? Studies cited in the Position Stand that support the primary claim or recommendation but contain serious flaws in the methodology or data.
↓ Studies cited in the Position Stand that fail to support the primary claim or recommendation.
* Studies not cited in the Position Stand that repudiate the primary claim or recommendation.

RANGE OF REPETITIONS

The Position Stand claims that several pioneering studies reported that training with 1-6 RM, and more specifically with 5-6 RM, is most effective for increasing maximal dynamic strength (p. 367). Three studies (19-21) are cited.

Berger (19) trained 199 male college students who performed one maximal set of the free-weight bench press 3x/wk for 12 weeks. Training for each of the six groups differed in the number of repetitions performed: 2 RM, 4 RM, 6 RM, 8 RM, 10 RM, or 12 RM. Although Berger (19) only reported the post-training means, his analysis of covariance revealed a significantly greater gain in strength (1 RM) for the 4 RM, 6 RM, and 8 RM groups compared with the 2 RM group, with no significant difference between the 4 RM, 6 RM, and 8 RM groups. The 4 RM and 8 RM groups showed a greater increase than the 2 RM and 10 RM groups. The strength gain for the 8 RM group was significantly greater than the 2 RM, 10 RM, and 12 RM groups, with no significant difference between the 2 RM, 10 RM, and 12 RM groups. Contrary to the claim in the Position Stand, Berger (19) reported that the 6 RM group produced strength gains that were not significantly different from the 4 RM and 8 RM groups (Table 2, p. 337).

O'Shea (20) randomly assigned 30 young, previously untrained, male college students to perform three sets of free-weight barbell squats 3x/wk for six weeks using one of three repetition ranges: 2-3 RM, 5-6 RM, or 9-10 RM. There was a significant increase in dynamic 1 RM squat (21.8, 26.7, and 20.4 %, 2-3 RM, 5-6 RM and 9-10 RM groups, respectively), static strength on a lower-body dynamometer (23.2, 15.5, and 21.1 %, 2-3 RM, 5-6 RM and 9-10 RM groups, respectively), and thigh girth (3-6 %). There was no significant difference among the groups for any of the changes. O'Shea (20) concluded that the three training protocols resulted in similar improvements in thigh girth, static strength and dynamic strength.

Weiss and colleagues reported the effects of resistance training with different ranges of repetitions on muscular strength in one publication (21) and hypertrophy in another (22). They randomly assigned 44 males (18-30 years), who were not previously engaged in any systematic physical training, to one of three training groups or a control group. Subjects performed four sets of free-weight barbell squats to muscular fatigue 3x/wk for seven weeks using a 3-5 RM, 13-15 RM, or 23-25 RM protocol. The three training groups significantly increased isokinetic knee-extensor strength (percent change not reported), with no significant difference among the groups. They also significantly increased 1 RM squat, with the 3-5 RM group showing a significantly greater increase than the 23-25 RM group, but not significantly greater than the 13-15 RM group (21). Weiss et al. (22) reported quadriceps muscle thickness using ultrasound. The three training groups significantly increased quadriceps muscle thickness, with no significant difference among the three protocols. Weiss et al. (21-22) concluded that performance of four sets of barbell squats within the range of 3 RM to 15 RM three days a week for seven weeks elicits similar increases in quadriceps thickness and strength.

In summary, the aforementioned studies (19-21) fail to support the claim in the Position Stand.

While some individuals may prefer a lower or higher range of repetitions for different muscle groups or for simple variation in their training, there is very little evidence to support the specificity of any particular range of repetitions. Although most resistance-training research involves previously untrained subjects, several other studies (23-26) in this population also suggest that particular outcomes are not related to a specific range of repetitions.

Bemben et al. (23) trained 25 females (41-60 years) 3x/wk for six months with either eight repetitions at 80 % 1 RM or 16 repetitions at 40 % 1 RM. Three sets for each of three lower-body and five upper-body exercises were executed on resistance machines, but only one set for each of four additional lower-body exercises: hip flexion, extension, abduction, and adduction. Three sets of exercise produced an average increase in strength of approximately 25 %, while one set produced almost twice the increase of about 49 %. Strength gains were similar as a result of performing different numbers of repetitions using either heavier or lighter resistance. That is, ~27 and ~22 %, 8-repetition and 16-repetition groups, respectively, for 3-set exercises, and ~44 and ~52 %, 8-repetition and 16-repetition groups, respectively, for 1 set exercises. As measured with ultrasound, both training groups showed significant improvements in rectus femoris cross-sectional area (~20 %) and biceps brachii cross-sectional area (~30 %), with no significant difference between groups.

Chesnut and Docherty (24) randomly assigned 24 previously untrained males (~24 years) to either a 4 RM or 10 RM group. Subjects exercised 3x/wk for 10 weeks performing seven upper-body exercises for 1-6 sets each. Both the 4 RM and 10 RM groups, respectively, significantly increased 1 RM elbow flexor strength (~13 and ~11 %) and elbow extensor strength (~22 and ~28 %), as well as the dynamic training load for the elbow flexors (~20 and ~25 %) and extensors (~22 and ~28 %), with no significant difference between the 4 RM and 10 RM groups for any of the strength gains. Both the 4 RM and 10 RM groups showed a significant increase in arm circumference (~2 and ~2.5 %, respectively) and cross-sectional area measured by MRI (~6 and ~7 %, respectively), with no significant difference between groups. Chesnut and Docherty (24) concluded that the 4 RM and 10 RM training protocols elicited similar increases in strength, muscle cross-sectional area and arm circumference.

Graves et al. (25) instructed 10 pairs of previously untrained identical twins (~19 years) to exercise the quadriceps muscles 2x/wk for 10 weeks. One of each twin performed one set of 7-10 RM and the matched twin executed one set of 15-20 RM variable resistance bilateral knee-extension exercise. Both groups had a significant increase in strength (13.2 and 12.8 %, 7-10 RM and 15-20 RM groups, respectively). There was no significant difference in the magnitude of strength gains between the identical twins, which were quintessentially matched groups.

Pruitt et al. (26) randomly assigned 26 females (65-82 years) to a control group or one of two progressive resistance-training groups (7 repetitions at 80 % 1 RM, or 14 repetitions at 40 % 1 RM), who performed three sets for each of 10 exercises 3x/wk for 52 weeks. Arm strength showed a significantly greater increase in the higher-repetition group (65.5 %) compared with the lower-repetition group (27.4 %). However, both groups (lower-repetition and higher-repetition, respectively) had significant gains in 1 RM for chest (10.1 and 15.4 %), shoulders (18.5 and 27.4 %), upper back (41.4 and 21.0 %), lower back (35.8 and 35.4 %), hips (50.9 and 66.4 %), and legs (47.6 and 42.4 %). There was no significant difference between groups in six out of seven outcomes.

All these studies (19-26) strongly suggest that within a reasonable range of repetitions, approximately 3 to 20, there does not appear to be a specific number of repetitions (e.g., 4-6, 7-10, 12-15, etc.) that will elicit more favorable gains in muscular strength, power, or hypertrophy. Therefore, the claim in the Position Stand that specific ranges of repetitions produce specific outcomes has very little scientific foundation.

Bone Mineral Density

The effect of the range of repetitions, and consequently, the amount of resistance, on bone mineral density is not discussed in the Position Stand, but may be relevant to establishing resistance-training protocols. For example, Kerr et al. (27) randomly assigned 56 previously untrained females (~57 years) to one of two resistance-training programs using free weights and machines 3x/wk for 52 weeks. All subjects performed three sets for each of five upper-body and five lower-body exercises, with 2-3 minutes rest between sets. One group used an 8-10 RM protocol and the other performed 20-25 RM. The exercising limb was allocated by randomization to either the left or right side with the contralateral limb acting as the non-exercising control. By using each subject as her own control, genetic and environmental aspects of bone density were controlled. Muscle strength (1 RM) significantly increased for all 10 exercises with no significant difference between the 8-10 RM group (~75 %) and the 20-25 RM group (~69 %). However, only the 8-10 RM group significantly increased bone density (measured by dual-energy x-ray absorptiometry) in both the upper and lower limbs compared with their non-exercised contra-lateral limbs.

Taaffe et al. (28) randomly assigned 36 previously untrained females (65-79 years) to a control group or one of two progressive resistance training protocols: 7 repetitions with 80 % 1 RM, or 14 repetitions with 40 % 1 RM. The two training groups performed three sets of leg-press, thigh-curl and knee-extension exercises 3x/wk for 52 weeks. Both the low-repetition and high-repetition groups, respectively, showed a significant increase in 1 RM leg press (~49 and 30 %), thigh curl (~62 and 81 %), and knee extension (~82 and 60 %), with no significant difference between the two training groups. However, the low-repetition group retained bone mineral density, while the high-repetition and control groups lost a significant amount (~2 %) of bone mineral density.

Table 3. Summary of Research Comparing Repetition Range.

Reference	Rating
Bemben et al. (23)	*
Berger (19)	↓
Chestnut & Docherty (24)	*
Graves et al. (25)	*
Kerr et al. (27)	*
O'Shea (20)	↓
Pruitt et al. (26)	*
Taaffe et al. (28)	*
Weiss et al. (21)	↓
Weiss et al. (22)	*

↑ Studies cited in the Position Stand that actually support the primary claim or recommendation.

? Studies cited in the Position Stand that support the primary claim or recommendation but contain serious flaws in the methodology or data.

↓ Studies cited in the Position Stand that fail to support the primary claim or recommendation.

* Studies not cited in the Position Stand that repudiate the primary claim or recommendation.

These two studies (27-28), in addition to the previously discussed studies (19-26) suggest that different ranges of repetitions produce similar strength gains. However, fewer repetitions with a heavier load may be required to increase bone density. In addition, based on the site-specific response of bone to exercise reported by Kerr et al. (27), a wide variety of exercises with a heavier rather than lighter resistance should probably be employed in order to stimulate maximal increases in bone density throughout the body.

The Position Stand recommends a specific range of repetitions for different outcomes such as muscular strength, hypertrophy, power, and endurance (p. 374). There are no references cited to support that recommendation.

In summary, the claim in the Position Stand that different ranges of repetitions specifically affect muscular strength, hypertrophy, power, and endurance is unsubstantiated (Table 3).

MULTIPLE SETS

The Position Stand claims that several studies reported multiple-set programs superior to single-set programs (p. 367) in previously untrained subjects (29-32), untrained subjects in long-term (~6 months) studies (33-34), and resistance-trained individuals (35-38). However, a close examination reveals that most of the studies cited do not support the claims in the Position Stand.

Previously Untrained Subjects

Berger (29) instructed nine groups of college-age males (N = 177) to perform the free-weight bench press as part of their beginning weight-training program using one of nine combinations of sets and repetitions (1 x 2 RM, 1 x 6 RM, 1 x 10 RM, 2 x 2 RM, 2 x 6 RM, 2 x 10 RM, 3 x 2 RM, 3 x 6 RM, or 3 x 10 RM) 3x/wk for 12 weeks. There was no control for the number of sets or repetitions performed for any of the other exercises in the program, and the participants were not equated or randomized before training. When Berger (29) combined his nine resistance-training groups according to the number of sets performed (1, 2 or 3 sets), he reported a significantly greater increase in 1 RM bench press as a result of performing three sets (25.5 %) compared with one set (22.3 %) or two sets (22.0 %). There was no significant difference between the 1-set and 2-set groups. Using an analysis of covariance to test for any significant interaction between sets and repetitions, Berger (29) noted that training with one, two, or three sets in discrete combination with two, six, or 10 repetitions (interaction) was not systematically more effective in improving strength than other combinations. Berger (29) reported no significant interaction, but then concluded that the combination of three sets and six repetitions was more effective than any other combination of sets and repetitions. In fact, Berger (29) reported no significant difference in the magnitude of strength gains in seven out of nine of his comparisons between groups who performed the same number of repetitions (two, six, or ten repetitions) for one, two, or three sets (Table 4, p. 176). Thus, this seminal study by Berger (29), which is frequently cited in support of multiple sets, shows that the majority of outcomes do not favor multiple sets.

Sanborn et al. (30) randomly assigned 17 previously untrained females (18-20 years) to either a single-set (8-12 reps) or multiple-set group (3-5 sets of 2-10 repetitions). All participants trained 3x/wk, involving the completion of five of the exercises 1x/wk and the other five exercises (including the squat) 2x/wk for eight weeks. Both groups showed a significant increase in 1 RM squat, with no significant difference between the single-set (24.2 %) and multiple-set groups (34.7 %). The increase in vertical jump was significantly greater in the multiple-set group (11.2 %) compared with the single-set group (0.3 %). However, the multiple-set group was encouraged to drive up on the balls of their feet when executing the squat, thereby involving additional muscle groups (gastrocnemius and soleus), which contribute to vertical jump performance. There was no explanation why these instructions were given to the multiple-set group and not to the single-set group. There was no significant change in body mass in either group. This study by Sanborn et al. (30) fails to substantiate the superiority of multiple-set protocols for increasing muscular size or strength.

Stone et al. (31) trained 34 previously untrained males 3x/wk for five weeks. There were different training modalities (8 machines and 9 free-weight exercises), different number of sets (1 set for all machines and 3-7 sets of free-weight exercises), and different number of repetitions (2, 12, or 15 for the machines, and 3, 6, 10, or 12 for free-weight exercises), executed at different *velocities* (maximum velocity for the free-weight exercises). Stone et al. (31) claimed that the free-weight group (3-7 sets) had a significantly greater increase in squat strength and vertical jump compared with the machine group (1 set). However, the authors also reported no significant difference in machine leg press strength, no significant increase in what they described as *power* (vertical jump and the Lewis formula) and no significant increase in body mass in either group. Stone et al. (31) did not report any pre- or post-training data or the percent change for any of the variables, which leaves this study open to different interpretations.

Stowers et al. (32) compared the effects of resistance training in subjects who performed four exercises 1x/wk, and four exercises (including the squat and bench press) 2x/wk for seven weeks. The 84 previously untrained college-age males were randomly assigned to either 1 x 10 RM, 3 x 10 RM, or a varied multiple-set protocol (5 x 10 wk 1-2, 3 x 5 wk 3-5, and 3 x 3 wk 6-7). Intensity was not described for the varied multiple-set group. All groups significantly increased 1 RM squat, with the varied multiple-set group (~25 %) showing a significantly greater increase than the 1-set (~16 %) and 3-set (~18.5 %) groups. Only the varied multiple-set group significantly increased vertical jump height (~10 %). The three groups showed a significant increase in 1RM bench press (~8.5 %), with no significant difference among groups. There was no significant difference between the 1-set and 3-set groups at the end of the 7-week study, and no significant increase in body mass in any group.

In summary, only one study (29) out of the four studies (29-32) cited in the Position Stand in support of multiple sets, which involved previously untrained participants, reported a small but statistically significant benefit for a multiple-set protocol.

Previously Untrained Subjects in Long-Term Studies

Borst et al. (33) recruited 31 healthy, sedentary males and females (~38 years) who were stratified by sex and quadriceps strength into one of three groups: single-set resistance training, multiple-set, or non-exercising control. The 1-set and 3-set groups performed seven exercises on a circuit of machines using an 8-12 range of repetitions to muscular fatigue 3x/wk for 25 weeks. The 3-set group (3 circuits) had a significantly greater increase in strength (~48 %) compared with the 1-set group (~32 %). There was no reported change in body mass or body composition in either group.

Marx et al. (34) randomly assigned 34 previously untrained females (~23 years) to a single-set, multiple-set, or control group for six months of resistance training. The single-set group trained 3x/wk performing one set of 8-12 RM for each exercise on two alternating circuits of 10 machines. The multiple-set group trained 4x/wk and performed 2-4 sets of 8-10 RM on Tuesday and Friday, and 3-5 RM, 8-10 RM, or 12-15 RM on Monday and Thursday on 7-12 free-weight and machine exercises. The multiple-set group showed a significantly greater strength gain in 1 RM bench press (46.8 %) and leg press (31.9 %) compared with the single-set group (12.2 and 11.2 %, bench press and leg press, respectively). There was no significant increase in lean body mass or decrease in percent body fat in the single-set group, while the multiple-set group showed a significant 3.3 kg increase in lean body mass and a significant decrease in percent body fat from 26.5 to 19.8 %.

In summary, both of these long-term (~6 months) studies (33-34) support the superiority of multiple sets in previously untrained subjects.

There are a plethora of studies (8, 23-24, 39-61) that show no significant difference in the magnitude of strength gains or muscle hypertrophy (whenever hypertrophy was measured) as a result of performing a greater number of sets. For example, Hass et al. (46) randomly assigned 42 males and females (20-50 years) to either a 1-set or

3-set protocol of 8-12 RM for each of nine exercises, which were completed in a circuit 3x/wk for 13 weeks. Subjects had been regularly performing resistance exercise 2.7x/wk for an average 6.2 years (minimum 1 year), which qualified them as *advanced* trainees according to the Position Stand. Each session was conducted and monitored by the investigators, with both groups progressing similarly and exerting equivalent efforts based of a rating of perceived exertion. The average increase in isometric knee extension torque (6.3 and 6.6 %, 1-set and 3-set groups, respectively), and isometric knee flexion torque (7.7 and 15.6 %) were not significantly different between groups. The significant increase in absolute muscular endurance for the chest press (49.5 and 66.7 %) and knee extension exercises (48.2 and 58.4 %), 1-set and 3-set groups, respectively, was not significantly different between groups. The 1-set group significantly decreased anterior thigh skin-fold and increased lean body mass (data not reported), while the 3-set group increased chest and biceps circumference and lean body mass, and decreased the sum of seven skin-folds and percent body fat (data not reported). There was no significant difference between groups for any of these variables.

Hass et al. (46) reported that the 1-set and 3-set groups showed a significant increase in 1 RM knee extension (~15 and 15 %), knee flexion (~10 and 13 %), chest press (~11 and 13 %), overhead press (~10 and 12 %), and biceps curl (~9 and 8%), for 1-set and 3-set groups, respectively. There was no significant difference in strength gains between the 1-set and 3-set protocols at any time point.

Out of the original 49 subjects, Hass et al. (46) removed five because of poor compliance, and two withdrew because of injuries. The seven subjects who did not complete the study were all from the 3-set group. Hass et al. (46) concluded that because there was no significant difference in outcomes between protocols, the single-set protocol represented a time-efficient method for developing muscular strength, endurance, and body composition, regardless of the individual's fitness level.

There are at least 18 additional resistance-training studies (62-79) whose primary purpose was to determine specific health-related benefits of resistance training in males and females of various ages performing total-body resistance training. All these studies used a 2-set protocol for each of three lower-body exercises and a 1-set protocol for each of eight upper-body exercises. The same resistance-training protocol was employed for all the studies (62-79). Hence, they provide fertile ground, with incredible replication, for examining the effect of one set or two sets on strength. Each study was well controlled and supervised, longer than most resistance-training studies (4-6 months compared with 6-12 weeks), and published in prestigious journals. The participants in each specific study served as their own controls; that is, these strength data were reported for upper- and lower-body exercises in the whole study group, rather than a comparison of two separate groups. Although the researchers did not report statistical comparisons between 1-set and 2-set exercises, the average reported increases in strength were similar for 1-set (~40 %) and 2-set (~36 %) exercises. The serendipitous, robust and unequivocal finding of similar strength gains in all of these studies (62-79) minimizes researcher bias, which may be inherent in studies specifically designed to investigate the effects of single versus multiple sets. Only one (64) of the aforementioned 18 studies (62-79) is cited in the Position Stand, and is cited relative only to the effect of resistance training on gastrointestinal transit time.

In summary, most of the research (8, 23-24, 39-61) shows that performing a greater number of sets does not significantly affect the magnitude of strength gain or muscular hypertrophy.

Resistance Trained Subjects

As Editor-in-Chief of the Journal of Strength and Conditioning Research, Kraemer (35) published a series of *Experiments* in that journal. The data for these *Experiments* were resurrected from a database that he accumulated as a coach, which we estimate was at least 15 years before their publication. *Experiments* 2, 3, and 4 are resistance-training studies, which collectively involved 118 male American football players (~20 years) with an average 2.9 years of resistance-training experience. The players performed either single-set or multiple-set (2-5 sets) resistance training using free weights and machines 3-4x/wk for 10-24 weeks. Compared with single-set groups, the multiple-set groups produced a three times greater increase in 1 RM bench press, five times greater increase in 1 RM leg press, seven times greater increase in hang clean, three times greater increase in body mass and decrease in percent body fat, four times greater increase in vertical jump, and 14 times greater increase in Wingate power test (collectively *Experiments* 2, 3, & 4).

In *Experiment* 5 of the series, Kraemer (35) gave 115 football players a survey questionnaire regarding their adherence to a single-set protocol. In fact, 89 % of the players reported using multiple-set protocols at home or during off hours at health clubs. It is not clear if these athletes are the same participants Kraemer (35) used for his database. However, if 89 % of his participants from a similar population of collegiate American football players were performing multiple sets in addition to their single-set program, the difference in outcomes reported by Kraemer (35) for *Experiments* 2, 3, and 4 are even more remarkable because both groups may have been following similar multiple-set protocols.

Kraemer (35) cites a study by Ostrowski et al. (53), which coincidentally appears immediately after Kraemer's study (35) in the same issue of that journal. Kraemer (35) claims that the results of Ostrowski et al. (53) contradict his data regarding the magnitude of strength gains as a result of multiple-set and so-called *periodization* resistance training. The study by Ostrowski et al. (53) is especially noteworthy because the subjects were advanced trainees and the resistance training was a *periodization* program, which is recommended throughout the Position Stand. The subjects were 35 males (~23 years) who were currently weight training for an average of 2.9 years, and had the ability to bench press at least 100 % of their body mass and squat with 130 % of their body mass. They were randomly assigned to perform one, two, or four sets of each exercise (3, 6, or 12 sets per muscle group per week) on 24 free-weight and machine exercises (6 exercises at each session), and they followed a split routine (2 days upper body and 2 days lower body each week) for 10 weeks. A 12 RM was used during weeks 1-4, 7 RM weeks 5-7, and 9 RM weeks 8-10. All sets were performed to muscular fatigue (same relative intensity of effort), with three minutes rest between sets. Ostrowski et al. (53) carefully manipulated only one variable, so that the only difference in training variables among the three programs was the number of sets. All other training variables were identical among the three groups. Ostrowski et al. (53) reported a significant increase in each of the three groups for 1 RM squat (7.5, 5.5, and 11.6 %), 1 RM bench press (4.0, 4.7, and 1.9 %), bench press power (2.3, 2.3, and 3.1 %), and bench press throw height (4.8, 7.7, and 4.9 %), 1-set, 2-set, and 4-set groups, respectively. There was no significant difference among the groups. Vertical jump did not significantly increase in any group. There was a significant increase in triceps brachia thickness (2.3, 4.7, and 4.8 %), rectus femoris hypertrophy (6.8, 5.0, and 13.1 %), rectus femoris circumference (3.0, 1.5, and 6.3 %), and body mass (2.0, 2.6, and 2.2 %), 1-set, 2-set, and 4-set groups, respectively. There was no significant difference among the three groups for any of the outcomes.

The average strength gains (7.5 %) reported by Ostrowski et al. (53) are within the predicted range established by Kraemer as Chairman of the Writing Group for the Position Stand. That is, the Position Stand predicts that *advanced* trainees who have years of experience and have attained significant improvements in muscular fitness can increase muscular strength approximately 10% over a period of four weeks to two years (p. 366). The Position Stand defines *elite* individuals as those athletes who are highly trained and have achieved a high level of competition. However, the average combined strength gain (19.6 %) for Kraemer's (35) *Experiments* 3 (15.4 %) and 4 (23.8 %), which involved Division III collegiate American football players, was two times greater than what is predicted in the Position Stand for advanced trainees, and almost 10 times greater than the ACSM's predicted increase for elite athletes. The strength gain (15.8 %) for *Experiment* 2 in the study by Kraemer (35), which involved highly-trained Division I collegiate American football players, is more than seven times greater than what is predicted for elite athletes (2 %) in the Position Stand.

Ostrowski et al. (53) reported no significant pre- to post-training changes in resting concentrations of testosterone (+17, +38, and –37 %), cortisol (-13, +97, and +26 %), or testosterone/cortisol ratio (+75, +73, and –57 %) in the 1-set, 2-set, and 4-set groups, respectively. Based on their results, Ostrowski et al. (53)

speculated that once a minimum threshold volume is attained (one set of each exercise), there is no advantage to an increased volume of training, and that higher volumes (four sets per exercise) may result in a decreased testosterone/cortisol ratio in some individuals.

These two contrasting studies by Kraemer (35) and Ostrowski et al. (53) deserve particular attention because the Writing Group for the Position Stand and the ACSM gave much greater precedence to the results reported by Kraemer (35) compared with Ostrowski et al. (53). The Kraemer study (35) is cited at least 14 times in the Position Stand and the study by Ostrowski et al. (53) is cited only once, and cited incorrectly. That is, the Position Stand claims that some studies have reported similar strength gains in *novice* individuals who performed either two sets or four sets of each exercise, and the study by Ostrowski et al. (53) is cited (p. 367). However, the subjects in the study by Ostrowski et al. (53) were at least in the *advanced* category, as defined in the Position Stand, and the comparison was among 1-set, 2-set, and 4-set groups.

Ostrowski et al. (53) concluded that their results demonstrated that low (1-set), moderate (2-set), and high-volume (4-set) protocols showed no significant difference in their effect on muscular strength, hypertrophy and power, and that the 1-set group represented a time-efficient method of resistance training, even in resistance-trained males (*advanced* trainees). Kraemer (35) concluded that if simple low-volume single-set protocols were really effective, as they were in the study by Ostrowski et al. (53), there would be little need for highly paid strength and conditioning specialists.

Kramer et al. (36) randomly assigned 53 moderately trained (not defined) males (~20 years) to a 1-set (8-12 RM), 3-set (10 RM), or varied multiple-set group (1-3 sets of 2-10 repetitions). All the groups trained 3x/wk for 14 weeks. The 1-set group performed the squat exercise with RM loads 2x/wk, while the two multiple-set groups executed the squat exercise with RM loads 1x/wk, and used a 10 % lighter resistance 1x/wk. Three so-called *assistance* exercises were also performed at each session using a similar training protocol of three sets of 5-10 repetitions in the multiple-set groups, and one set of 8-12 RM in the 1-set group. All the subjects significantly increased 1 RM squat (12, 26, and 24 %, 1-set, 3-set, and varied multiple-set groups, respectively), with the two multiple-set groups improving significantly more than the 1-set group. Neither body mass nor body composition changed significantly.

Kraemer et al. (37) randomly assigned 24 female collegiate tennis players (~19 years) to one of three groups: single-set, multiple-set or control. The single-set group performed one set of 8-10 repetitions and the multiple-set group rotated each session using 4-6, 8-10, or 12-15 repetitions for 2-4 sets of each of 17 exercises, with 1-3 minutes rest between sets. The single-set group performed each repetition in what the authors describe as a slow, controlled manner, and the multiple-set group was instructed to execute repetitions with moderate-to-explosive muscle actions. Both groups trained 2-3x/wk for nine months. There were 17 exercises executed with at least five exercises performed unilaterally. Assuming at least one minute to set up and perform each of the 22 exercises (22 + 5), with an average of three sets per exercise (3 x 22 = 66 sets x 1 min = 66 min), and an average of two minutes rest between sets (66 x 2 = 132 min), each session for the multiple-set group would require approximately 198 minutes. However, Kraemer et al. (37) reported that all workouts were completed within 90 min.

With the exception of pre-training age, height and body mass, Kraemer et al. (37) did not report any data for absolute or percent changes pre- to post-training. The following estimates of the changes are taken from Figure 3 (p. 630) presented in the study (37). The significant increase in 1 RM free-weight bench press was more than three times greater in the multiple-set group (~27 %) compared with the single-set group (~8 %). The single-set group showed a significant increase of ~8 % in leg press strength and the multiple-set group increased ~24 %, which was three times greater than the single-set group. In the free-weight military press, the single-set group increased strength by ~12 % and the multiple-set group increased ~33 %. After nine months of strength training there was no significant improvement in the single-set group for Wingate cycle power, tennis-serve velocity or vertical jump. The multiple-set group had a significant increase in cycle power (~17 %), tennis-serve velocity (~25 %), and vertical jump (~53 %).

Although body mass did not change significantly in either group, the multiple-set group reduced body fat from ~23 to ~18 % (37). Calculating this 3.1 kg loss of body fat and the reported average 60.4 kg body mass, which did not change from pre- to post-training, the female athletes in the multiple-set group purportedly gained 3.1 kg of lean body mass in nine months. Kraemer et al. (37) concluded that the high volume multiple-set program elicited superior increases in muscular strength, power, lean body mass, and tennis serve velocity, as well as a significant decrease in percent body fat.

Kraemer et al. (37) noted that the goal of the resistance-training program was to increase tennis-specific fitness components beyond the gains produced by typical tennis practice. They also noted that in an attempt to minimize the learning effect on

Table 4. Summary of Research Comparing Single and Multiple Sets.

Reference	Rating
Bemben et al. (23)	*
Berger (29)	?
Berger (39)	*
Berger (40)	*
Borst et al. (33)	↑
Capen (41)	↓
Chestnut & Docherty (24)	*
Ciriello et al. (42)	*
Coleman et al. (43)	↓
Dudley et al. (44)	↓
Girouard & Hurley (62)	*
Graves et al. (45)	*
Hass et al. (46)	↓
Hisaeda et al. (47)	*
Hurley et al. (63)	*
Jacobson (48)	↓
Koffler et al. (64)	*
Kosmahl et al. (49)	*
Kraemer (35)	?
Kraemer et al. (37)	↓
Kramer et al. (36)	↑
Larshus et al. (50)	*
Leighton et al. (51)	*
Lemmer et al. (65)	*
Lott et al. (66)	*
Martel et al. (67)	*
Marx et al. (34)	↑
Menkes et al. (68)	*
Messier & Dill (52)	↓
Miller et al. (69)	*
Nicklas et al. (70)	*
Ostrowski et al. (53)	↓
Parker et al. (71)	*
Pollock et al. (54)	↓
Reid et al. (55)	↓
Rhea et al. (72)	*
Roth et al. (73)	*
Rubin et al. (74)	*
Ryan et al. (75)	*
Ryan et al. (76)	*
Ryan et al. (77)	*
Ryan et al. (78)	*
Sanborn et al. (30)	↓
Schlumberger et al. (38)	↑
Schmidtbleicher & Buehrle (56)	*
Silvester et al. (8)	↓
Starkey et al. (57)	↓
Stone et al. (31)	?
Stowers et al. (32)	↓
Treuth et al. (79)	*
Wenzel & Perfetto (58)	*
Westcott (59)	*
Westcott (60)	*
Withers (61)	*

↑ Studies cited in the Position Stand that actually support the primary claim or recommendation.
? Studies cited in the Position Stand that support the primary claim or recommendation but contain serious flaws in the methodology or data.
↓ Studies cited in the Position Stand that fail to support the primary claim or recommendation.
* Studies not cited in the Position Stand that repudiate the primary claim or recommendation.

the potential strength gains, the subjects were familiarized (at least three training sessions) with all resistance-training protocols before initiating the study. There is no mention of previous resistance training in this study. Therefore, the inference is that the female tennis players were not resistance-trained individuals, which is contrary to what is claimed in the Position Stand (p. 367). Perhaps the most questionable aspect of this study (37) was the inability of this single-set group of previously untrained females to elicit any significant change in performance variables, and produce only a very small strength gain (~10 %) after nine months of resistance training.

Schlumberger et al. (38) randomly assigned 27 females (~26 years) to a 1-set, 3-set, or control group. The 1-set and 3-set groups performed 6-9 RM for each of seven exercises 2x/wk for six weeks. Both groups had a significant increase in 1 RM bilateral knee extension, with the gains for the 3-set group (15.8 %) significantly greater than the 1-set group (6.7 %). Only the 3-set group showed a significant increase in 1RM bench press (10 %). Schlumberger et al. (38) first noted that the participants had a minimum of six months resistance training, but then noted two times that the basic resistance-training experience ranged from 3-6 months. Consequently, it is not possible for readers to determine if the participants were *novices* or *intermediate* trainees, as defined in the Position Stand.

In summary, only two of the studies cited in the Position Stand support the superiority of multiple sets over a single set in moderately trained (36) and in novice or intermediate trainees (38). Although there is a lack of evidence to suggest that single-set protocols are superior to multiple sets (except for time efficiency), most of the resistance-training research fails to support the superiority of multiple-set training, while strongly supporting the efficacy of single-sets (Table 4).

REST PERIODS

The Position Stand claims that the amount of rest between sets and exercises significantly affects training adaptations. Two references (80-81) are cited in an attempt to support their assertion that there are greater strength gains as a result of longer rather than shorter rest periods (p. 368).

Pincivero et al. (80) compared 40 seconds rest (group 1) and 160 seconds rest (group 2) between sets of ten maximal unilateral concentric-only isokinetic knee-extension and knee-flexion exercise, which were performed at 90°/s. The 15 volunteers (~22 years), who did not perform resistance training for at least six months prior to this investigation, trained 3x/wk for four weeks. They executed four sets during each of the first three sessions, with an additional set at each of the nine remaining sessions (wk 2-4). Isokinetic dynamometry was used to evaluate the effects of training on the quadriceps and hamstrings, and the distance for a single-leg hop was designated as the functional performance assessment.

Quadriceps average power (trained and untrained limbs combined) at 60°/s (-0.96 and 5.2 %, groups 1 and 2, respectively) and quadriceps peak torque at 180 °/s (2.3 and 8.4 %, groups 1 and 2, respectively) were the only variables that were significantly affected by rest interval manipulation (Table 4, p. 232), with the change in group 2 significantly greater than group 1. An objective evaluation of the results reveals that 12 out of the 14 variables measured on the dynamometer, and the functional performance measure, were not significantly affected by rest interval manipulation (80).

Robinson et al. (81) assigned 33 moderately trained males (~20 years) to one of three groups with different rest time between sets of exercise: group 1 (180 seconds), group 2 (90 seconds), or group 3 (30 seconds). Subjects executed five sets of 10 RM for the squat, push-press, clean-pull and power-snatch exercises, and three sets of 10 RM for the bench press, dead lift, shrug, row, and crunch exercises. Training was scheduled 4x/wk and each exercise was performed 2x/wk for five weeks. Robinson et al. (81) stated that the increase in 1 RM squat was significantly greater for group 1 (7 %) compared with group 3 (2 %). However, they did not state whether or not the difference between group 1 (7 %) and group 2 (6 %), or between group 2 and group 3, was significantly different. Therefore, the claim by Robinson et al. (81) that their data suggest a rest-period continuum, with longer rest periods producing greater strength gains, is not supported by their data. Furthermore, there was no significant difference among the groups for any of the other 10 measured variables: body mass, skin folds, girth circumference, vertical jump, vertical jump power index, cycle peak power, average peak power, average power, total work, and average total work.

Neither of these cited studies (80-81) supports the opinion in the Position Stand that at least 2-3 min of rest are required between sets and exercises, and neither study involved advanced trainees.

In summary, the claims in the Position Stand that the rest time between sets and exercises is dependent on the specific goals of a particular exercise, that shorter rest periods decrease the rate of strength gains, and that multiple-joint exercises require longer rest periods than single-joint exercises on machines, are bereft of any scientific support (Table 5).

Table 5. Summary of Research Comparing Rest Periods.

Reference	Rating
Pincivero et al. (80)	↓
Robinson et al. (81)	↓

↑ Studies cited in the Position Stand that actually support the primary claim or recommendation.
? Studies cited in the Position Stand that support the primary claim or recommendation but contain serious flaws in the methodology or data.
↓ Studies cited in the Position Stand that fail to support the primary claim or recommendation.
∗ Studies not cited in the Position Stand that repudiate the primary claim or recommendation.

MUSCLE ACTIONS

The Position Stand claims that some advanced programs incorporate supra-maximal eccentric muscle actions to maximize gains in muscular strength and hypertrophy (p. 366). One study (82) is cited to support the efficacy of this training technique.

Keogh et al. (82) reported a cross-sectional comparison of force, power, EMG, time under tension, and lactate response to eight different bench press techniques performed on a plyometric power system. Keogh et al. (82) suggested that supra-maximal eccentric muscle actions (~six 4-second eccentric-only repetitions with 110 % concentric 1 RM) impose a greater overload than heavy weight training (6 RM) on the musculature. However, this was not a longitudinal resistance-training study. Consequently, Keogh et al. (82) and the authors of the Position Stand are merely expressing their opinion about the benefits of supra-maximal eccentric muscle actions. There is no evidence cited to support that opinion.

Because the Position Stand cites Koegh et al. (82) when referring to “supra-maximal” eccentric muscles actions, the inference is that the Position Stand is referring to eccentric-only muscle actions with a resistance greater than the concentric 1 RM. Several resistance-training studies (83-87) have compared the effects of training with “supra-maximal” eccentric muscle actions with concentric-only muscle actions.

Concentric-Only versus Eccentric-Only (“supra-maximal”) Muscle Actions

Hakkinen and Komi (83) reported the results of resistance training with different muscle actions in a group of competitive junior Olympic weightlifters, as well as in a group of non-competitive resistance trainees. Thirteen competitive weightlifters (17-23 years) performed exercises described as the snatch, clean and jerk, squat, snatch and clean pull, and arm press 4x/wk for 12 weeks. Group A progressively performed all the exercises concentrically using 70-100 % of concentric maximum. Group B performed a similar routine except they executed eccentric-only muscle actions for 25 % of the snatch and clean pulls, squat, seated press, and lower-back exercises with a progression of 100-130 % of the concentric maximum (sets and repetitions not reported for either group). There were five different dynamometer tests for the knee-extensor muscles involving isometric, concentric, and eccentric muscle actions, and each group significantly improved in two of those tests. Group B showed a significantly greater increase in the clean and jerk (13.5 %) compared with group A (5.7 %).

However, both groups significantly increased the snatch (7.1 and 9.9 %, groups A and B, respectively), with no significant difference between groups.

The 27 non-competitive males (20-30 years) who comprised groups C, D, and E trained 3x/wk with the bench press and squat, performing 1-6 repetitions per set for concentric muscle actions (80-100 %) and 1-3 repetitions per set for eccentric muscle actions (100-130 %), totaling 16-22 repetitions per exercise (83). Group C performed all the exercises concentrically. Group D performed approximately half the squats and bench presses eccentrically. Group E executed about three-quarters of the exercises eccentrically. In the five tests on the dynamometer for the knee extensors, group C did not significantly improve on any test, group D significantly increased four variables, and group E on two variables. The three groups significantly increased 1 RM squat, with the gains in groups D (29.2 %) and E (28.6 %) significantly greater than group C (20.3 %). Group C (15.2 %), D (19.5 %), and E (12.3 %) significantly increased 1 RM bench press. The gains in bench-press strength were not significantly different among the groups. Thigh girth significantly increased for group C (1.4 %), D (2.4 %), and E (1.4 %), with no significant difference among the groups (83).

Johnson et al. (84) trained eight college students 3x/wk for six weeks. The four exercises were described as the arm curl, arm press, knee flexion and knee extension. Exercises were performed concentric-only with 80 % 1 RM unilaterally, and eccentric-only ("supra-maximal") with 120 % 1 RM on the contra-lateral side. Two sets of 10 repetitions were employed for concentric-only muscle actions, and two sets of six repetitions for eccentric-only muscle actions. Both types of training produced significant gains in isometric strength in all subjects, except for elbow flexion in the eccentric-only limb, and elbow flexion and knee flexion in the concentric-only limb. Dynamic strength increased for the arm-curl (~32 and 29 %), arm-press (~55 and 60 %), knee-flexion (~25 and 25 %), and knee-extension (~30 and 30 %) exercises, concentric-only and eccentric-only muscle actions, respectively. There was no significant difference between concentric (80 % 1 RM) and eccentric (120 % 1 RM) training for any of the dynamic strength measures.

Jones and Rutherford (85) assigned five previously untrained males and one female (~28 years) to perform concentric-only knee-extension exercise with one limb using 80 % 1 RM, and eccentric-only knee-extensions with the contra-lateral limb using a resistance 145 % greater than what was used for the concentric-only training. Subjects performed four sets of six repetitions (~2-3 s/muscle action) for each limb with one-minute rest between sets 3x/wk for 12 weeks. Assistants either lifted or lowered the resistance for the two different protocols. Strength increased 15 % in the concentric-only limb and 11 % in the eccentric-only limb, with no significant difference in the strength gains. Computerized tomography revealed a significant increase in quadriceps cross-sectional area in the concentric-only (5.7 %) and eccentric-only limbs (3.5 %), with no significant difference between limbs.

Komi and Buskirk (86) randomly assigned 31 males (~20 years) to a concentric, eccentric, or control group. The exercising groups performed either maximal concentric or maximal eccentric right elbow flexor muscle actions six times a day 4x/wk for seven weeks. The exercising tension was approximately 40 % greater in the eccentric group. The increase in maximal eccentric tension was significantly greater in the eccentric group (15.6 %) compared with the concentric group (6.7 %). Maximal isometric tension (8.6 %) and right arm girth (1.8 %) showed a significant increase only in the eccentric group. There was a significant increase in maximal concentric tension (the more practical functional ability to lift a resistance) and there was no significant difference between the concentric (12.1 %) and eccentric (15.8 %) groups.

Seliger et al. (87) assigned 15 highly trained rugby players (~26 years) to perform several upper-body and lower-body free-weight resistance exercises 2x/wk for 13 weeks. One group performed concentric-only muscle actions with 90-95 % of maximal resistance, and another group performed eccentric-only muscle actions with 145-150 % of maximal resistance (specific exercises, repetitions and sets not reported). Both groups showed a significant increase in bench press (~13 and 9 %) and squat strength (~49 and 49 %) in the concentric-only and eccentric-only groups, respectively. There was no significant difference in strength gains between groups.

Most of the results from these five studies (83-87) do not support the superiority of "supra-maximal" eccentric exercise. In the two studies (83, 86) that showed some advantage to "supra-maximal" eccentric muscle actions, there was no comparison group that performed conventional concentric and eccentric muscle actions, which is a combination of lifting and lowering the same resistance. It is important to note that "supra-maximal" eccentric-only exercise is not typically performed because it requires either specially designed exercise machines to lift the resistance, or highly motivated, knowledgeable, trustworthy training partners. With the exception of the study by Jones and Rutherford (85), which is cited in the Position Stand merely to show that four sets of resistance exercise will significantly increase muscular strength (p. 367), these studies (83-84, 86-87) are not cited in the Position Stand.

Concentric and Eccentric versus Concentric and Accentuated-Eccentric Muscle Actions

Another form of training with an eccentric resistance greater than the concentric resistance is accentuated eccentric exercise. It is accomplished with the help of a spotter, special exercise machines, or by using two limbs to perform the concentric muscle action and one limb for the eccentric muscle action. However, there were only two published studies (88-89) that compared this type of training with traditional concentric-eccentric training (lifting and lowering the same resistance).

Ben-Sira et al. (88) randomly assigned 60 previously untrained females (~21 years) to one of four experimental groups or a control group. The subjects performed bilateral concentric-only (65 % 1 RM), eccentric-only (65 % 1 RM), conventional concentric/eccentric (65 %/65 % 1 RM), or concentric/accentuated eccentric (65 %/130 % 1 RM) knee-extensor muscle actions for three sets of 10 repetitions 2x/wk for eight weeks. The 65/130 % group lifted the resistance (65 % 1 RM) with both limbs, and alternated lowering the resistance (130 % 1 RM) with one limb. Dynamic knee-extensor strength gains in the conventional group (19 %) and the eccentric-accentuated group (23 %) were significantly greater than the control group (~3 %), but not significantly different from each other. Post-hoc comparisons of the groups revealed no significant difference.

Godard et al. (89) randomly assigned 28 previously untrained males and females (~22 years) to a concentric/eccentric (con/ecc), concentric/accentuated eccentric (con/ecc+), or a control group. Resistance was initially set at 80 % 1 RM for both concentric and eccentric muscle actions in the con/ecc group. In the con/ecc+ group, resistance for the eccentric component was 40 % greater than the concentric resistance. Both groups performed one unilateral set of 8-12 RM knee extensions 2x/wk for 10 weeks. There was a significant increase in 1 RM (~95 and 94 %) and thigh girth (~6 and 5 %) in the con/ecc and con/ecc+ groups, respectively, with no significant difference between groups. Godard et al. (89) concluded that using the same amount of resistance for concentric and eccentric muscle actions was just as effective as the addition of accentuated eccentric muscle actions for producing increases in strength and thigh girth.

Table 6. Summary of Research Comparing Muscle Actions.

Reference	Rating	
Ben-Sira et al. (88)		*
Godard et al. (89)		*
Hakkinen & Komi (83)		*
Johnson et al. (84)		*
Jones & Rutherford (85)	↓	
Keogh et al. (82)	↓	
Komi & Buskirk (86)		*
Seliger et al (87)		*

↑ Studies cited in the Position Stand that actually support the primary claim or recommendation.
? Studies cited in the Position Stand that support the primary claim or recommendation but contain serious flaws in the methodology or data.
↓ Studies cited in the Position Stand that fail to support the primary claim or recommendation.
* Studies not cited in the Position Stand that repudiate the primary claim or recommendation.

Several studies suggest that resistance training with exercises that provide resistance for a combination of concentric and eccentric muscles actions (i.e., conventional resistance training), as compared with concentric-only resistance training, produce significantly greater strength gains (44, 90-93), retention of strength gains (91), and muscle hypertrophy (94).

In summary, there is very little evidence cited to support the superiority of supra-maximal eccentric training, as claimed in the Position Stand (Table 6). Two studies (83, 86) reported an advantage in some but not all measures of strength with supra-maximal eccentric training. However, the protocols were not compared to resistance training that typically includes both concentric and eccentric muscle actions. The research (88-89) suggests that there is no additional benefit to performing accentuated eccentric muscle actions compared with traditional concentric/eccentric muscle actions (lifting and lowering a similar resistance).

FREQUENCY OF TRAINING

The Position Stand cites several resistance-training studies (54, 95-97) and then recommends that novices (those with no resistance training experience or who have not trained for several years) train the entire body two to three times per week (p. 369). Although this is a reasonable recommendation, the references prior to that statement may not be relevant to the recommended training frequency.

The Position Stand cites a study by Gillam (95) to show that 3x-5x/wk is superior to 1x and 2x/wk resistance training (p. 369). Gillam (95) randomly assigned previously untrained male high school students to one of five groups who performed the free-weight bench-press exercise 1x, 2x, 3x, 4x, or 5x/wk for nine weeks. The 3x (32.3 %), 4x (29.0 %), and 5x/wk (40.7 %) groups showed a significantly greater increase in 1 RM bench press than the 1x/wk group (19.5 %), and the gains in the 3x and 5x/wk groups were significantly greater than the 2x/wk group (24.2 %). There was no significant difference between the 1x and 2x/wk groups, or between the 3x and 4x/wk groups. The protocol used by Gillam (95) was highly unusual and although 90 % of the participants completed the study, it is highly doubtful that most healthy adults would readily comply with a training protocol of 18 sets 1 RM 3-5x/week for each of the targeted muscle groups.

The Position Stand notes that a 4x/wk training frequency has been shown (96) to be superior to 3x/wk training (p. 369). Hunter (96) compared the effects of two frequencies of training with a slightly different distribution of the same amount of exercise for the two groups. Forty-six previously untrained males and females (~23 years) performed 7-10 RM for each of seven exercises (bench press, squat, power clean, behind-the-neck press, biceps curl, behind-the-neck pull-down, and thigh curls) for seven weeks. The 3x/wk group performed three sets of each exercise on alternate days. The 4x/wk group executed two sets of each exercise 3x/wk on three consecutive days and three sets of each exercise on the fourth consecutive day. Hunter (96) noted that the number of weekly sets (nine) for each of the seven exercises was identical for both groups. Bench press strength (14.1 and 21.9 %), bench press endurance (41.4 and 59.9 %), and chest circumference (0.2 and 3.2 %) significantly increased in both the 3x and 4x/wk groups, respectively, with a significantly greater increase in the 4x/wk group. Both groups had significant improvements in biceps circumference (2.6 and 4.3 %), standing long jump (4.6 and 4.5 %), lean body mass (0.7 and 1.0 %), and percent body fat (from 16.6 to 15.8 % and 15.1 to 14.4 %), 3x and 4x/wk groups, respectively, with no significant difference between groups for any of these variables. Although this study does report a more favorable response for the 4x/wk group in three out of the seven measured variables, each exercise was performed on four consecutive days. Therefore, Hunter's (96) results do not support the recommendation of two to three days a week in the Position Stand.

The study by McLester et al. (97) involved advanced trainees (those with years of resistance training experience) and is discussed shortly.

The Position Stand cites a study (54) in an attempt to show that a frequency of three times per week (3x/wk) is superior to 1x/wk resistance training (p. 369). Pollock et al. (54) compared the effects of one set of 8-12 RM (dynamic) or two sets (dynamic + isometric) resistance exercise on the cervical extensors in four groups (N = 78) of previously untrained males and females (~28 years) either 1x or 2x/wk for 12 weeks. Isometric strength was evaluated at eight angles throughout 126^o range of cervical flexion. Pollock et al. (54) reported that the increase in isometric strength was significantly greater for the 2x/wk groups only at 126^o of cervical flexion. Dynamic training loads significantly increased in both 1x/wk groups (35.0 and 42.0 %, dynamic and dynamic + isometric groups, respectively) and both 2x/wk groups (40.9 and 43.5 %, dynamic and dynamic + isometric groups, respectively), with no significant difference between the groups. There was no 3x/wk group in this study (54), as claimed in the Position Stand. The authors of the Position Stand apparently selected the one isometric strength measure that supported their opinion about frequency of training and incorrectly claimed that it was a result of training 3x/wk. They failed to report that the strength gains in seven out of eight isometric measures and the increase in dynamic resistance showed no significant difference between the 1x/wk and 2x/wk groups.

Several studies (described below) have reported similar responses in previously untrained participants as a result of training 1x, 2x or 3x/wk (98-100), 1x or 3x/wk (101), and 3x or 5x/wk (102). One study reported that 3x/wk was better than 2x/wk (103); while another showed 2x/wk was superior to 3x/wk (104). In addition, one study (105) found no difference between 2x and 3x/wk, and that both frequencies were better than 1x/wk.

Carpenter et al. (98) reported the results of lumbar-extension exercise in 23 males and 18 females (~35 years). The participants were rank ordered by peak isometric torque and randomly assigned to perform one set of 8-12 RM 1x, 2x, 3x, 1x/2wk (every other week), or no training. All the training groups significantly increased peak isometric torque at the seven angles tested (from 17.2 % at 72^o flexion to 123.1 % at 0^o flexion), with no significant difference in isometric strength gains among the groups. The four training groups significantly increased the training resistance (8-12 RM) after 20 weeks, with no significant difference among the 1x (46.3 %), 2x (51.5 %), and 3x/wk (48.1 %) groups. The only significant difference was a greater increase in strength for the 2x/wk group compared with 1x/2wk (33.4 %).

Graves et al. (99) placed 72 males (~31 years) and 42 females (~28 years) in rank order by peak isometric strength and randomly stratified them to one of five training groups: 1x/2wk, 1x, 2x, 3x/wk dynamic training, or 1x/wk isometric training. All the participants in the dynamic training groups performed one set (8-12 RM) of lumbar-extension exercise for 12 weeks. The isometric group performed maximal isometric strength tests at each of seven angles once a week. The five groups significantly increased maximal isometric torque at all seven angles, with no significant difference in the magnitude of responses among the groups. The resistance used for dynamic training (8-12 RM) significantly increased in the 1x/2wk (26.6 %), 1x (38.9 %), 2x (41.4 %), and 3x/wk (37.2 %) groups. The increase was significantly greater for the 1x, 2x, and 3x/wk groups compared with the 1x/2wk group but there was no significant difference in strength gains among the 1x, 2x, and 3x/wk groups.

Taaffe et al. (100) randomly assigned 34 previously untrained males and 19 females (~69 years) to a 1x, 2x, or 3x/wk training group, or a control group. The exercise groups performed three sets of eight repetitions with 80 % 1 RM for each of five upper-body and three lower-body exercises for 24 weeks. Dual energy X-ray absorptiometry (DEXA) revealed a significant increase in lean body mass for the 1x (4.9 %), 2x (2.8 %) and 3x/wk (1.7 %) groups, which were all significantly greater than the control group (-5.9 %). The average increase in strength for the eight exercises was significant for group 1x (37.0 %), 2x (41.9 %) and 3x/wk (39.7 %). There was no significant difference in upper body, lower body, or whole body strength gains among the three training groups at any time point.

After initially training (1 x 6 RM) 79 males (18-23 years) in the free-weight squat for three weeks, Berger (101) randomly assigned his seven weight training classes to seven groups for an additional six weeks of training. All the participants performed only one repetition at each session with 66, 80, and 90 % 1 RM 2x/wk in groups 1, 2 and 3, respectively. Groups 1, 2 and 3 also performed the 1 RM 1x/wk. Group 4 executed the 1 RM 3x/wk, group 5 used 66 % 1 RM 3x/wk, and group 6 performed the 1 RM 1x/wk. Group 7 was the control. Group 5 (66 % 1 RM 3x/wk) and 7 (control group) did not significantly increase strength. There was a significant increase in 1 RM squat for group 1 (17.8 kg), 2 (15.7 kg), 3 (12.5 kg), 4 (15.0 kg), and 6 (10.6 kg). There was no significant difference in the magnitude of strength gains among these groups. Berger (101) concluded that training 1x/wk with the 1 RM was just as effective as training 3x/wk.

Rozier and Schafer (102) trained the right knee extensors in 40 females (18-23 years) either 3x or 5x/wk for six weeks. All subjects performed three sets of eight repetitions on an isokinetic dynamometer and were encouraged to apply maximal force throughout each knee extension. Both groups significantly increased peak isometric torque (17 and 12 %, 3x and 5x/wk groups, respectively) and peak isokinetic torque (15 and 12 %, 3x and 5x/wk groups, respectively). There was no significant difference in the magnitude of strength gains as a result of training 3x or 5x/wk.

Gregory (103) trained 152 previously untrained males (~21 years) either 2x or 3x/wk for 14 weeks. Both groups performed three sets of 6-10 RM for seven exercises, and were tested pre- and post-training on four of those exercises (bench press, seated press, leg press, and biceps curl). Compared with the 2x/wk group, the 3x/wk group had a significantly greater increase in the seated press (17.5 and 13.1 %, 3x and 2x/wk groups, respectively) and the leg press exercises (12.6 and 9.6 %, 3x and 2x/week groups, respectively). Both groups (2x and 3x/wk, respectively) showed a significant increase in 1 RM bench press (16.7 and 17.9 %) and biceps curl (12.9 % and 15.1 %), with no significant difference between groups. The overall mean difference in strength gains between the groups was 2.7 %. Gregory (103) noted that the 3x/wk group demonstrated a more rapid increase in strength during the first seven weeks and found diminishing returns from weeks 8-14, while the 2x/week group showed a more uniform increase in strength throughout the 14 weeks.

Carroll et al. (104) randomly assigned 17 previously untrained males and females (~19 years) to a 2x, 3x/wk, or control group. The 2x/wk group trained for nine weeks (18 sessions), while the 3x/wk group trained for six weeks (18 sessions). Both training groups performed three sets of repetitions that ranged from 4-6 RM to 15-20 RM, depending on the exercise (4 upper-body and 3 lower-body). After completing 18 sessions, 1 RM squat significantly increased in the 2x (22.6 %) and 3x/wk (32.2 %) groups, with no significant difference between groups. The 2x/wk group demonstrated a significant increase (31.2 %) in peak isometric knee-extension and isokinetic strength (28.8, 38.1, 57.7, and 61.7 % at 1.05, 3.14, 5.24, and 8.73 rad/s, respectively). There was no significant increase in the 3x/wk group.

DeMichele et al. (105) randomly assigned 98 males and females (~30 years) to one of three training groups (1x, 2x or 3x/wk) or a control group. Subjects performed one 8-12 RM set (one set left-to-right and one set right-to-left) of dynamic torso-rotation exercise for 12 weeks. The average increase in peak isometric torque at the seven angles tested was 4.9, 16.3, and 11.9 %, group 1x, 2x, and 3x/wk, respectively. There was no significant difference between the 2x and 3x/wk groups at any of the seven angles tested. The increase in resistance used for training (8-12 RM) was significantly greater for the 2x (37.0 %) and 3x/wk (34.3 %) groups compared with the 1x/wk group (no significant change pre- to post-training), with no significant difference between the 2x and 3x/wk groups. DeMichele et al. (105) noted that the dropout rate was inversely related to training frequency (4, 7, and 15 dropouts in groups 1x, 2x, and 3x/wk, respectively). Because the 2x/wk frequency resulted in better adherence and equal strength gains compared with the 3x/wk group, DeMichele et al. (105) recommended a training frequency of 2x/wk.

For intermediate trainees (those with approximately six months of consistent resistance training experience), the Position Stand recommends a similar frequency of 2x-3x/wk total-body workouts, or split routines (upper-body/lower-body) to provide a greater volume of exercise. There is no resistance-training study cited to support the efficacy of a greater volume of exercise or split routines in intermediate trainees. The only reference cited is a book by Fleck and Kraemer (106).

There are only two studies (97, 107) cited in the Position Stand that employed previously trained participants and compared different training frequencies (p. 369). The study by McLester et al. (97) is cited in the Position Stand in the section relating to novice trainees. However, this study involved advanced trainees as defined in the Position Stand. McLester et al. (97) randomly assigned 25 males and females (~26 years), who had been exercising each muscle group at least twice a week and had approximately 5.7 years of recreational resistance-training experience (advanced trainees according to the Position Stand), to a 1x or 3x/wk resistance-training program for 12 weeks. The 1x/wk group performed three sets of 5-8 RM for each of five upper-body and four lower-body exercises, while the 3x/wk group performed one set of 3-10 RM for each exercise. There was no significant change in six out of the seven health-related variables (resting diastolic blood pressure, sum of nine circumferences, sum of three skin folds, percent body fat, body mass, and lean body mass) from pre- to post-training in either group. Resting systolic blood pressure significantly decreased 5 % in the 1x/wk group and 3 % in the 3x/wk group. Both groups significantly increased upper-body strength (20.2 and 32.4 %, 1x and 3x/wk groups, respectively), with no significant difference in strength between groups for any of the upper body exercises. There was a significant increase in the four lower-body exercises (23.5 and 37.4 %, 1x and 3x/wk groups, respectively). There was no significant difference between groups except for the leg press, with the 3x/wk group (46.1 %) significantly greater than the 1x/wk group (22.3 %). However, there was no significant difference between the 1x and 3x/wk groups in eight out of the nine strength measures. McLester et al. (97) concluded that 1x/wk training produced comparable strength gains to 3x/wk training.

The study by Hoffman et al. (107) deserves particular attention because Hoffman et al. (107) noted in their introduction that previous studies (prior to 1990) involved relatively untrained participants. In addition, the Hoffman study is one of only two studies (97, 107) cited in the Position Stand on frequency of training that involved the target population specified as advanced trainees. Hoffman et al. (107) trained 61 male Division I American football players (~20 years) with approximately three years resistance-training experience. Players were not randomly assigned to different programs, nor were the different programs randomly assigned. Each player was given the option to select a training frequency of 3, 4, 5, or 6 days/week. Although it does not guarantee that the groups would have been equated on all variables, rank order and randomization should have been performed, as this would have attempted to create equivalent groups that were essentially similar on all or most of the relevant variables. If these strategies were followed, then similar results would be expected in the experimental groups if the independent variable (frequency of training) made no difference. If the results were different among the groups, the difference could be attributed to the independent variable. It is also not clear if the independent variable should have been the self-selection of frequency rather than the frequency of training per se. Based on these research design limitations, this study should be considered descriptive or observational, which precludes the determination of a causal relationship.

Subjects performed 4-5 sets of 2-10 repetitions in the free-weight bench press and squat, which were the resistance-training exercises tested and reported. In the Methods section (p. 77), Hoffman et al. (107) claimed that the so-called "core" exercises were operationally defined as the bench press and squat; however, in their Table 3 (p. 78) there are six exercises designated as core exercises. Therefore, the exact number of so-called "core" exercises is not clear. Hoffman et al. (107) also failed to describe exactly what they meant by the term "core" exercises. Hoffman et al. (107) claimed that the subjects trained the core exercises 2x/wk in the 4day/wk and 6day/wk groups, and 3x/wk in the 3day/wk and 5day/wk groups. There were different distributions of the 40-44 so-called *assistance* exercises and all the subjects performed three sets of 10 RM for each exercise. The 3 day/week group exercised the eight listed body parts on M, W, F, the 4day/wk group trained the chest, shoulders, triceps, neck on M, Th, and legs, back, biceps, forearms on Tu, F. The 5day/wk group exercised the chest, triceps, legs, neck on M, W, F, and back, shoulders, biceps, forearms on Tu, Th, and the 6day/wk group trained the chest, triceps on M, Th, legs, shoulders, neck on Tu, F, and back, biceps, forearms on W, Sa. In addition to the resistance-training program, all the athletes participated in a football-conditioning program, which consisted of speed training, plyometics, flexibility, agility, and endurance exercises 2x/wk. Body mass, 1 RM bench press, 1 RM squat, 40-yard (~37 m) sprint, vertical jump, 2-mile (~3.2 km) run, sum of skin folds, thigh circumference, and chest circumference were the nine variables measured and reported pre- and post-training (10 weeks).

Hoffman et al. (107) claimed that the weekly number of sets for the 6day/wk group was similar to the 4day/wk and 5day/wk group. However, their claim contradicts the data reported in their Table 4 (p. 79) that shows 158 weekly sets for the 6 days/wk group compared with 122 sets for the 4 day/wk group. The 6 days/wk group actually executed a 30 % greater number of sets than the 4 day/wk group.

The increase in 1 RM bench press (1.8, 3.5, 3.2, and 4.0 %, 3, 4, 5, and 6 day/wk groups, respectively) was significant for only the 5 days/wk group. The gains in 1 RM squat (5.2, 7.3, 7.5, and 6.5 %, 3, 4, 5, and 6 day/wk groups, respectively) were significant for all groups except the 3 day/wk group. Hoffman et al. (107) claimed that resistance training in the 5day/wk group, who performed the bench-press exercise 3x/wk, had the greatest impact on strength development because it was the only group to significantly improve 1 RM bench press (3.2 %). However, the 3day/wk group also performed the bench press and squat exercises 3x/wk, but showed no significant increase in either bench-press or squat strength. The 6 day/wk group, who performed the bench press exercise 2x/wk, had a significantly greater pre-training 1 RM bench press (9.8 %), a 4.0 % increase in 1 RM, a similar standard deviation post-training, with less than half the number of participants (n = 11) compared with the 5 day/wk group (n = 23). Perhaps a post-training, between-group statistical comparison would have shown no significant difference between groups; or if there were a similar number of participants in both groups, the gains in bench-press strength would have been similar.

There was no significant difference in pre-training age, height, lifting experience, and time for a 2-mile run among the groups. However, there were significant differences pre-training among the groups for body mass, 1 RM squat, 1 RM bench press, sum of skin folds, thigh circumference, and chest circumference (107). With pre- and post-training data available and the statistical analysis reported for within-group pre- to post-training differences, post-training statistical comparisons among the groups would have been helpful to readers in the interpretation of the data (107).

Hoffman et al. (107) claimed that training 4 and 5 days/wk were superior to 3 and 6days/wk because a greater number of variables improved in those groups. However, the 4 days and 6 days/wk groups, who performed the so-called “core” exercises 2x/wk, significantly improved nine variables, and the 3 and 5days/wk groups, who performed the core exercises 3x/wk, also improved nine variables. That is, the groups that performed the “core” exercises 2x/wk improved in the same number of variables (nine) as the groups performing the “core” exercises 3x/wk. The only obvious difference is that the 3x/wk groups performed 155 sets each week compared with 140 in the 2x/wk groups, and more importantly, they had to perform a greater weekly volume of exercise per muscle group as a result of the greater frequency of training the “core” exercises. A similar comparison can be made between the 6 day/wk (n = 11) and 3 day/wk (n = 12) groups who trained the core exercises either 2x/wk (6 day/wk group) or 3x/wk (3x/wk group). Both groups significantly improved in three variables.

Based on the claim by Hoffman et al. (107) that there are problems with athletes regarding time constraints and compliance to training programs, perhaps their conclusion should have been that the groups improved in the same number of variables training the “core” exercises 2x or 3x/wk, but the groups that trained 2x/wk accomplished this with fewer weekly sets. Therefore, the conclusions by Hoffman et al. (107), and the statement in the Position Stand that football players training 4-5 days/week achieved better results than those who trained three or six days/week are unsubstantiated.

Regarding the study by Hoffman et al. (107), the Position Stand claims that the 5 day/wk and 6 day/wk programs elicited a greater increase in vertical jump performance compared with 3 day/wk and 4 day/wk programs (p. 372). In fact, there was no post-training between-group comparative analysis reported by Hoffman, and more importantly, there was no significant increase in vertical jump for any group. The data reported by Hoffman et al. (107) render the claim in the Position Stand unfounded.

Because it is not explained in the Position Stand, it should be noted that the study by Hoffman et al. (107) is the only frequency study cited where the participants may have performed specific exercises (e.g., the so-called "core" exercises) at a frequency (x/wk) that differed from the number of weekly exercise sessions (days/wk). In all the other studies (54, 95-105) the frequency of training (x/wk) was the number of times per week that an exercise was performed and that frequency coincided with the number of sessions/week. That is, the subjects performed the designated exercises at each session.

The Position Stand claims that advanced (those individuals with years of resistance training experience who have attained significant improvements in muscular fitness) weightlifters, powerlifters, and bodybuilders train 4-6 days a week, and that the frequency of training for elite (those athletes who are highly trained and achieved a high level of competition) weightlifters, power lifters, and bodybuilders may total 18 sessions a week (p. 369). Because the references cited are books by Fleck and Kraemer (106) and Zatsiorsky (108), the authors of the Position Stand are apparently basing these claims on their observations of this specific population. However, reports of the pervasive use of anabolic-androgenic steroids among competitive bodybuilders, weightlifters, and power lifters (109-112) render the athletes who use these drugs a highly questionable source of reference for what is purported to be a scientific document for healthy adults (The Position Stand).

Split Routines

The Position Stand states that advanced lifters train 4-6 days a week, and that elite weightlifters and bodybuilders may benefit from using very high frequency training; for example, two sessions a day, 4-5 days a week (p. 369). A study by Hakkinen and Kallinen (113) is cited to support a greater increase in strength and muscle cross-sectional area when training volume was divided into two sessions a day compared with one session a day. However, Hakkinen and Kallinen (113) employed a split routine that is not typically used by the experienced weightlifters and bodybuilders noted in the Position Stand. Ten females (~29 years) with at least 2-3 years of resistance training experience performed approximately 10 sets of squats with 70-100 % 1 RM (1-3 repetitions/set, 18-22 total repetitions) and four sets of leg press or knee extension exercises with 60-70 % 1 RM (5-10 repetitions/set, 20-40 total repetitions) either in one session a day, 3x/wk for three weeks or two sessions a day 3x/wk for three weeks. Half the group used the two sessions/day protocol for the first three weeks followed by the one session/day protocol for the next three weeks; the other half of the group followed the same procedure in reverse order. Percent body fat, which was estimated by skin fold measurement, did not change significantly at any time. With the exercises divided into two sessions a day, there was a significant increase in strength (5.1 %), body mass (1.3 %), and quadriceps femoris cross-sectional area (3.9 %). When the subjects performed the exercises in one session a day, Hakkinen and Kallinen (113) reported no significant increase in strength (0.1 %) or body mass (-0.3 %) in their Results section (p. 120). However, the one session/day pre- and post-training values in their Table 2 (p. 120) show an increase in strength from 2,258 to 2,555 N (13.2 %) with the same number of subjects and a similar standard deviation as shown for the two daily sessions.

Putting aside the questionable data, the practical application of the Hakkinen and Kallinen (113) resistance-training protocol for exercising the major muscle groups in healthy adults is questionable—regardless of how the exercises are distributed. That is, the subjects in the Hakkinen and Kallinen (113) study executed 14 sets (10 sets of squats and four sets of knee extension or leg press exercises) 3x/wk to stimulate the quadriceps. Therefore, advanced trainees who wish to stimulate the major muscle groups of the hips, thighs, legs, lower back, upper back, midsection, chest, shoulders, neck, arms using the Hakkinen and Kallinen (113) protocol of 14 sets of each exercise for each muscle group, would require approximately 140 sets 3x/week. With the rest time recommended in the Position Stand of at least 2-3 minutes between sets and exercises, the weekly time required for resistance training (140 sets x 3x/week x 3 minutes = 1260 minutes) is 21 hours—an overwhelming commitment for many healthy adults.

In summary, most of the frequency studies report no significant difference in response to performing an exercise 2x or 3x/wk, and some studies report similar results training 1x, 2x or 3x/wk. The Position Stand claims that progression may not necessitate a change in frequency for training each muscle group, but that a greater frequency of training may enable a greater volume of exercise for each muscle group. The implication that a greater overall volume of exercise (as a result of a greater frequency of training or split routines) is more effective for enhancing muscular strength, hypertrophy, power, and endurance in any specific population is unsubstantiated (Table 7). There is no evidence cited in the Position Stand to suggest that split routines, as advanced trainees commonly perform them (different muscle groups on different days), are superior to whole-body sessions. The only evidence for split routines is the very unusual protocol of Hakkinen and Kallinen (113), which could require several hours of training each day.

Table 7. Summary of Research Comparing Training Frequency.

Reference	Rating
Gillam (95)	↑
Hakkinen & Kallinen (113)	?
Hoffman et al. (107)	↓
Hunter (96)	↓
McLester et al. (97)	↓
Pollock et al. (54)	↓

↑ Studies cited in the Position Stand that actually support the primary claim or recommendation.
? Studies cited in the Position Stand that support the primary claim or recommendation but contain serious flaws in the methodology or data.
↓ Studies cited in the Position Stand that fail to support the primary claim or recommendation.
∗ Studies not cited in the Position Stand that repudiate the primary claim or recommendation.

PERIODIZATION (VARIED MULTIPLE-SET PROTOCOLS)

The Position Stand makes several provocative claims that form the basis for the ACSM's complex and time-consuming recommendations. The first claim is that progression in long-term resistance training requires the manipulation of program variables such as the amount of resistance, exercise selection, order of exercises, number of sets and repetitions, as well as rest time between sets and exercises, and that manipulation of these variables differentially affects specific goals such as muscular strength, hypertrophy, power, and endurance (p. 364). The only reference cited in an attempt to support this opinion is a review by Stone et al. (114).

The second claim in the Position Stand is that each training phase is designed to emphasize a particular physiological adaptation; for example, that hypertrophy is stimulated during the initial *high-volume phase*, whereas strength is maximally developed during the later *high-intensity phase* (p. 365). The only references cited are a review by Fleck (115) and a theoretical model of resistance training by Stone et al. (116).

The Position Stand also claims that the magnitude of strength gains are dependent on the types of muscle actions, intensity, selection and order of exercises, volume of exercise, rest between sets, and frequency of training (p. 366). The only reference cited is a review by Tan (117).

No resistance-training studies are cited to support any of the aforementioned claims in the Position Stand.

The previous sections in this document demonstrate that different training modalities, repetition duration, range of repetitions, number of sets, rest time between sets and exercises, and frequency of training produce very little, if any, difference in outcomes. Therefore, there is no reason to believe the planned manipulation of these variables (so-called "periodization") would significantly affect specific outcomes.

Only three of the studies (118-120) cited in the Position Stand attempted to control volume and intensity (using the authors' definitions of volume and intensity), and compared so-called "periodization" to "traditional" (non-periodized models) resistance training.

Baker et al. (118) matched 33 males (~20 years) with at least six months resistance-training experience, and then randomly assigned them to one of three programs, which included the bench press and squat. Subjects in the "linear periodization"group performed 5 x 10 RM wk 1-4, 5 x 5 RM wk 5-8, 3 x 3 RM and 1 x 10 RM wk 9-11, and 3 x 3 RM wk12. The "undulating periodization" group followed a protocol of 5 x 10 RM wk 1-2, 5 x 6 RM wk 3-4, 5 x 8 RM wk 5-6, 5 x 4 RM wk 7-8, 5 x 6 RM wk 9-10, and 4 x 3 RM wk 11-12. The "traditional" group used 5 x 6 RM throughout the study. After training 3x/wk for 12 weeks, all three groups (linear periodization, undulating periodization, and traditional groups, respectively) showed a significant increase in 1 RM bench press (11.6, 16.4 and 12.5 %), 1 RM squat (27.7, 28.4 and 26.1 %), vertical jump (3.8, 10.1, and 9.3 %), and lean body mass (2.8, 3.3 and 3.2 %). There was no significant difference among the groups for any of the measured variables. Baker et al. (118) concluded that performance outcomes and changes in body composition were similar for periodization and traditional resistance training.

Herrick and Stone (119) randomly assigned 22 previously untrained females (~22 years) to either a progressive resistance program of 3 x 6 RM (traditional) or a varied training protocol of 3 x 10 RM wk 1-8, 3 x 4 RM wk 10-11, and 3 x 2 RM wk 13-14 (periodization), with one-week active rest (low-intensity stationary cycling) between each period. All subjects performed three upper-body and three lower-body exercises 2x/wk for 15 weeks. Both groups, traditional and periodization, respectively, significantly increased 1 RM bench press (25.2 and 31.9 %) and squat (46.3 and 53.5 %). There was no significant difference in strength gains between the traditional and periodization groups. Herrick and Stone (119) concluded that their results did not support the benefits of periodization over traditional progressive resistance training, and they recommended either training protocol for female athletes who wish to maximize strength.

Schiotz et al. (120) matched 22 male Army volunteers (~22 years) based on their years of military training, and then randomly assigned them to a periodization or traditional resistance-training program. Both groups performed the bench press, squat and seven other exercises 2x/wk. The traditional group executed four sets of six repetitions beginning with 80 % 1 RM. The periodization group performed the bench press and squat using 50-105 % 1 RM with different combinations of sets and repetitions throughout the study (5 x 10 wk 1-2, 3 x 10, 1 x 8 and 1 x 6 wk 3, 2 x 8 and 3 x 5 wk 4, 1 x 8, 1 x 6 and 3 x 5 wk 5, 1 x 8 and 4 x 5 wk 6, 1 x 8, 2 x 5, 1 x 3 and 1 x 1 wk 7, 2 x 5, 1 x 3, 1 x 2, and 1 x 1 wk 8, and 2 x 3 and 4 x 1 wk 9-10). The periodization group showed a significant decrease in body fat from 11.6 to 9.9 %. However, there was no significant increase in lean body mass in either group. The increase in 1 RM bench press (10 and 6 %) and 1 RM squat (13 and 14 %) was significant for periodization and traditional resistance training, respectively, but not significantly different between groups. Nor, was there any significant difference between groups in the four Army Ranger Challenge physical performance tests. Schiotz et al. (120) concluded that trainees could follow either a periodization or a traditional resistance-training program and develop similar improvements in muscular strength and performance.

The Position Stand cites five studies (121-125) in an attempt to show that periodization is superior to traditional resistance training (p. 365).

O'Bryant et al. (121) randomly assigned 90 previously untrained males (~19 years) to one of two resistance training programs. Group 1 performed 5 x 10 wk 1-4, 3 x 5 wk 5-8, and 3 x 2 wk 9-11 (intensity not described), while group 2 used 3 x 6 RM for 11 weeks. Subjects performed four exercises (including the free-weight squat) 2x/wk, and five exercises 1x/wk. O'Bryant et al. (121) claimed that the increase in 1 RM squat (estimated from Figure 1, p. 28) was significantly greater for group 1 (~37 %) compared with group 2 (~32 %), as was the increase in cycle ergometer power (~17 and 7 %, groups 1 and 2, respectively). There was no significant increase in body mass in either group of these previously untrained males. O'Bryant et al. (121) concluded that the continuous use of the same number of sets and repetitions resulted in a monotonous training program for group 2, and the lack of variation may have been responsible for the difference between groups in 1 RM squat and cycle power.

O'Bryant et al. (121) also claimed that longitudinal studies suggested that the 3 x 6 RM protocol, which they used to compare with the program in group 1, had previously produced the greatest gains in strength. However, the only resistance-training study cited by O'Bryant et al. (121) was by Berger (39). In fact, Berger (39) compared 3 x 6 RM, 3 x 10 RM, and 6 x 2 RM bench press protocols 3x/wk for nine weeks. The 48 college-age males significantly increased their 1 RM bench press (21, 20, and 17 %, respectively), with no significant difference between the groups. Therefore, Berger's study (39) does not support the claim by O'Bryant et al. (121).

O'Bryant et al. (121) also concluded that their results agreed with three studies by Stone and colleagues (126-128). However, in the first reference Stone et al. (126) did not compare different training models. They trained nine previously sedentary college-aged males 6x/wk for eight weeks. All the subjects followed the same resistance-training protocol. There was no report of any strength measure. The second reference was a review by Stone et al. (127), and the third reference is a book written by Stone and O'Bryant (128). None of these references (126-128) cited by O'Bryant et al. (121) is a resistance-training study that supports the opinion of O'Bryant et al. (121), thereby rendering their claim unfounded and misleading.

Stone et al. (122) reported on one experiment (*Experiment* #1) and two observations (*Observation #1 and #2*). In *Experiment* #1, Stone et al. (122) randomly assigned 20 previously untrained college-age males to what the authors describe as either an experimental (group 1) or control group (group 2). The protocol for group 1 was 5 x 10 (wk 1-3), 5 x 5 (wk 4), 3 x 3 (wk 5), and 3 x 2 (wk 6), while group 2 performed 3 x 6 for weeks 1-6. The level of intensity or percent 1 RM is not described for either group. Both groups performed squats, thigh curls and bench presses 2x/wk, and mid-thigh pulls, floor pulls, and the seated behind-the-neck press 1x/wk for six weeks. The only strength measure reported was the 1 RM squat, with the gain for group 1 (~32 kg) significantly greater than group 2 (~23 kg). There was no report of pre- or post-training data, or percent change for any strength measure.

Stone et al. (122) used the Lewis formula to estimate anaerobic power. They reported a significantly greater gain for group 1 (+4.5 kg/m/s) compared with group 2 (-2.0 kg/m/s). However, Harman et al. (129) reported that the Lewis formula underestimated peak power by 70.1 % and average power by 12.4 % compared with force-platform determination. Harman et al. (129) concluded that the validity of the Lewis formula has never been supported in a scientific peer-reviewed journal, and consequently is not a valid method for estimating average or peak power generated by a subject performing a jump and recommended that its use be discontinued.

Stone et al. (122) noted that group 1 showed an approximate 3.5 % decrease in percent body fat at three weeks and an increase of ~1.1 % during the next three weeks, for a net decrease of ~2.4 %. The changes in percent body fat for group 2 were ~0.1 % at three weeks and ~0.5 % at six weeks. The percent body fat was significantly lower for group 1. Group 1 increased lean body mass by a remarkable ~2.4 kg in the first three weeks, but lost ~2 kg in the next three weeks, with a net gain of 0.4 kg. Group 2 increased by 1.1 kg at three weeks and lost ~2.4 kg during the next three weeks, for a net loss of 1.3 kg of lean body mass. At the end of the 6-week study there was no significant difference in vertical jump height between group 1 (~2.4 cm) and group 2 (~2.2 cm).

Stone et al. (122) claimed that previous studies by Berger (29) and O'Shea (20) have shown that strength gains are most efficiently accomplished with three sets of six repetitions. However, their assumption is weakly supported by one of those studies (29), which is discussed in the Multiple Sets section of this document, and not supported at all by the other study (20), which is discussed in the Range of Repetitions section of this document.

Observations #1 *and* #2 by Stone et al. (122) were not controlled research experiments, and are bereft of any statistical analysis. Therefore, they lend no support for so-called periodization training.

Stone et al. (123) randomly assigned 21 college-age males to either a traditional program or one of two varied multiple-set resistance-training programs. Previous resistance-training experience was not reported. The squat was executed 2x/wk for 5 x 6 RM in group 1, and 2x/wk for 5 x 10 RM, 5 x 5 RM, 3 x 3 RM (wk 1-4, 5-8, 9-12, respectively) in group 2. Group 3 performed 3-5 sets of 3-5 repetitions (RM on Monday, 15 % below RM on Friday) that varied eight times during the 12-week study. There was a significant increase in 1 RM squat for group 2 (15 %) and group 3 (15.4 %), but the change (10 %) for group 1 (n = 1) was not significant. Stone et al. (123) claimed that periodization resistance-training programs produce superior results compared with constant-repetition programs. However, no between-group statistical comparisons were reported. Stone et al. (123) noted that four out of the five subjects in group 1 were removed from the study because they complained of monotony or lack of variation, leaving only one subject in group 1 for evaluation; a dropout rate (80 %) unlike any other resistance-training study cited in this document. The evaluation of only one subject seriously limits any practical application of this study (123).

Willoughby (124) trained 48 males (~20 years) 2x/wk for 12 weeks in four physical education classes. Treatments were randomly assigned to each group. Group 1 performed 3 x 10 RM and group 2 used 3 x 6-8 RM for 12 weeks, while group 3 followed a protocol of 5 x 8-10 RM wk 1-4, 4 x 5-7 RM wk 5-8, and 3 x 3-5 RM wk 9-12. Group 4 refrained from resistance training. The 1 RMs for each exercise were divided by the subject's body mass to estimate the strength to body mass ratio. Neither absolute strength nor percent change in strength was reported, only the ratio of strength to body mass at baseline and post-training. Willoughby (124) did not report post-training values for body mass. Consequently, because it is not known if body mass changed as a result of the resistance training, readers cannot calculate the absolute or percent strength gains from the published data.

For the bench press and squat exercises, Willoughby (124) reported that groups 1, 2, and 3 increased strength significantly more than group 4 (control). It was also reported that strength gains were significantly greater in group 3 compared with groups 1 and 2, and group 2 was significantly greater than group 1. Based on the data reported by Willoughby (124) in Table 1 (p. 137), the correct calculation of the pre- to post-training increase in squat strength for group 2 yields a value of 0.560 rather than 0.385 shown in Table 1 (p. 137). This discrepancy questions whether the 0.676 increase in strength for group 3 was significantly greater than the actual reported 0.560 increase for group 2 (124).

In a different study, Willoughby (125) randomly assigned 92 males (~20 years) to one of three training groups who performed the free-weight bench press and squat exercises 3x/wk for 16 weeks. The subjects were previously trained and considered eligible for the study if they could bench press 120 % of their body mass and squat with 150 % body mass. Although at least three years of resistance training were required for participation, the subjects abstained from resistance training for six months prior to the study. Willoughby (125) stated that it was important to note that the 6-month abstinence constituted a state of detraining in which subjects could have responded differently.

Group 1 performed five sets of 10 repetitions with 78.9 % 1 RM and group 2 performed six sets of eight repetitions with 83.3 % 1 RM for the duration of the study. Group 3 followed a varied program that comprised five sets of ten repetitions with 78.9 % 1 RM wk 1-4, either four or six sets of eight repetitions with 83.3 % 1 RM wk 5-8, three sets of six repetitions with 87.6 % 1 RM wk 9-12, and three sets of four repetitions with 92.4 % 1 RM wk 13-16. Willoughby (125) stated in his Abstract (p. 2) that the protocol for group 3 was six sets of eight repetitions for weeks 5-8. However, in his Methodology section (p. 4) he stated that the protocol for group 3 during the same time interval was four sets of eight repetitions. Consequently, readers cannot determine the exact number of sets. If there was a misprint in either the Abstract or the Methodology sections, that misprint appeared in two publications (125, 130).

This study by Willoughby (125) was apparently published in the *Journal of Human Movement Studies* (130) two years prior to its publication in the *Journal of Strength and Conditioning Research* (125). That is, the same database was apparently used for both publications (125, 130) and the only difference was the way that the main dependent variable (strength to body mass ratio) was presented. That is, Willoughby reported the absolute changes in the strength to body mass ratio from pre-training to weeks 4, 8, 12, and 16 in one publication (125), and reported changes in the strength to body mass ratio from interval to interval (0-4, 4-8, 8-12, 12-16, and 0-16 weeks) in his other publication (130).

Willoughby (125, 130) reported that he monitored and calculated the training volume (total mass lifted per week) for the bench press and squat exercises during each of the four training intervals for weeks 0-4, 4-8, 8-12, and 12-16. The weekly training volume was the product of the amount of resistance times the number of repetitions per set times the number of sets per session times the number of sessions per week for 92 participants (125, 130). The total training volume for each interval is identical in both publications (125, 130) as evidenced by the identical graphs in Figure 1 on page five (125) and Figure 1 on page 242 (130). Willoughby reported that his results revealed a significant multivariate volume difference among the four groups [$F(4,128) = 15.65$; $p<0.0001$], and significantly different training volume for the bench press and squat exercises [$F(2,66) = 8.26$; $p<0.0001$]. These values are identical in both publications (125, 130).

Willoughby (125) reported significant gains in bench press strength to body mass ratio for groups 1, 2 and 3 after four weeks of training, with no significant difference among the groups. At eight, 12 and 16 weeks, the increase for group 3 was significantly greater than groups 1 and 2, with no significant difference between groups 1 and 2. In his Discussion section (p. 6) Willoughby (125) claimed that the decreased volume and increased intensity for group 3 at 8, 12 and 16 weeks resulted in significantly greater gains than groups 1 and 2. However, Figure 1 (p. 5) and the Results section (p. 5) show that the training volume was not significantly different among groups 1, 2 and 3 at eight weeks (125).

In his Results section (p. 6) Willoughby (125) reported that groups 2 and 3 showed a significantly greater gain in the squat strength to body mass ratio compared with group 1 at four, eight and 12 weeks. However, Figure 3 (p. 6) shows no significant difference between groups 1, 2 and 3 at four weeks. At 16 weeks, group 3 showed a significantly greater increase compared with groups 1 and 2, with group 2 significantly greater than group 1. Willoughby (125) claimed that the decreased volume and increased intensity for group 3 did not produce significantly greater gains over group 2 at four, eight and 12 weeks. However, Willoughby's Figure 1 (p. 5) shows that the volume was not significantly different among groups 1, 2 and 3 at four and eight weeks (125).

Willoughby (125) reported that the resistance was changed only after each 1 RM session (every 4 weeks), and that the resistance for each specific 10 RM, 8 RM, 6 RM, and 4 RM was derived from testing the 1 RM. That is, 78.9, 83.3, 87.6, and 92.4 % 1 RM was used for the 10 RM, 8 RM, 6 RM, and 4 RM, respectively. Willoughby cited a study by Berger (131) in both his publications (125, 130) as his rationale for establishing the specific resistance for each RM. However, Berger (131) tested the 1 RM, 5 RM and 10 RM and interpolated the percentage scores for the 2 RM, 3 RM, 4 RM, 6 RM, 7 RM, 8 RM, and 9 RM. He reported data for only one exercise (bench press) and indicated that his table contained approximate values, which were starting points to determine an RM by trial and error. Berger's (131) standard deviations for the percentage of the 5 RM and 10 RM were 3.36 and 3.66, respectively. Therefore, if an individual has a 1 RM bench press of 100 kg and uses the 89.8 kg (89.8 % 1 RM) for the 5 RM, the standard deviation of percentage (89.8 - 3.66 = 86.44 % x 100 kg 1 RM = 86.44 kg, and 89.8 + 3.66 = 93.2 % x 100 kg 1 RM = 93.2 kg) establishes a range of resistance that exceeds the values in Berger's (131) Table 1 (p. 110) for the 4 RM (92.4 kg) and 6 RM (87.6 kg). With a range of values for the 5 RM that exceeds the estimated values used by Willoughby (125, 130) for the 4 RM and 6 RM, predicting a maximal effort of a specific repetition of every set in 92 subjects is highly unlikely.

The only way to determine if the last repetition in a set is a maximal effort (e.g., 4, 6, 8, 10 RM, etc.) is to attempt another repetition. Willoughby (125) claimed that spotters were available to assist a subject in the event that fatigue may have prohibited completion of the designated number of repetitions. However, he reported that all the subjects in each training group were able to complete the designated number of repetitions with the assigned resistance without assistance from spotters (125). This reported scenario questions whether the last repetition was a true RM for the free-weight bench press and squat exercises. In addition, with a given percent of the 1 RM (e.g., 80 %), subjects will differ from one another by one to several repetitions at the point of muscular fatigue for a specific exercise (132), as well as differ from one exercise to another within an individual (133). Both of these studies (132-133) are discussed in our Local Muscular Endurance section. Therefore, the use of a specific percent 1 RM to establish the exact resistance for a specific RM such as 4 RM, 6 RM, 8 RM, or 10 RM is questionable. If each set in this study was not a maximal effort on the last repetition, then Willoughby's (125) description of multiple sets of RM (e.g., 5 sets of 10 RM in group 1) is not accurate. If the subjects in groups 1 and 2 were really able to exert a maximal effort on exactly the last repetition for each of the five sets in group 1 and for the last repetition on each of the six sets in group 2 of the bench press and squat exercises three times a week for 16 weeks, then it would lend support to Willoughby's claim that these multiple-set protocols may have resulted in over-training (125).

In the previous publication (130) of this study (125), Willoughby reported no significant difference in bench press among groups 1, 2 and 3 at 4, 8 and 12 weeks (p. 241). However, Willoughby (130) claimed in his Abstract (p. 233) that the increase in strength to body mass ratio for groups 2 and 3 was significantly greater than group 1 at 12 weeks, and his Table 1 (p. 240) shows groups 1 and 3 significantly greater than group 2 at 12 weeks. Willoughby (130) claimed in his Results (p. 241-3) that group 3 showed greater gains than groups 1 and 2, with group 2 significantly greater than group 1 during weeks 13-16. However, in his Abstract (p. 233) and in Table 1 (p. 240) he reported no significant difference between groups 1 and 2 from weeks 13-16. Willoughby (130) claimed in his Discussion (p. 243-4) that after 12 weeks of training there was no significant difference between groups 1 and 2. However, Willoughby noted in his Abstract (p. 233) that group 2 was significantly greater than group 1 at 12 weeks, and Table 1 (p. 240) showed that group 1 was significantly greater than group 2 at 12 weeks (130).

In the squat exercise, Willoughby (130) reported no significant difference in strength to body mass ratio among groups 1, 2 and 3 during the first eight weeks (p. 243). However, he noted in his Abstract (p. 233), in Table 2 (p. 241), and his Discussion (p. 244) that group 3 showed a significantly greater increase than groups 1 and 2 during weeks four through eight. Willoughby (130) reported in his Results (p. 243) that group 3 was significantly greater than groups 1 and 2, and that group 2 was significantly greater than group 1 at 12 weeks. However, he claimed in his Abstract (p. 233) that groups 2 and 3 were significantly greater than group 1, and in his Discussion (p. 244) claimed that there was no significant difference between groups 1 and 2 at 12 weeks. At 16 weeks group 3 had a significantly greater gain compared with groups 1 and 2 (130).

Willoughby (125) also claimed that previously published resistance training studies (32, 122, 134-135) suggest that so-called periodization programs produce significantly greater strength gains than traditional resistance training. The studies by Stone et al. (122) and Stowers et al. (32) were previously discussed in this section and our Multiple Sets section, respectively. Christian and Seymour (134) trained only one group of subjects. There was no comparative training group or control group. Therefore, this study (134) does not support Willoughby's claim that one training protocol is superior to another (125).

Swanson and Moffatt (135) assigned 32 previously untrained college-age males to one of two training groups (performing similar exercises) or a control group. One group performed 3 x 6 RM and the other used 3 x 10 RM wk 1-2, 3 x 5 RM wk 3-5, and 3 x 3 RM wk 6-8. Both groups trained 2x/wk for eight weeks. There was a significant increase in muscular strength (1 RM bench press and squat) and girth measurements in both groups (data not reported). However, there was no significant difference in strength gains or girth measurement between the two training groups. Contrary to the claim by Willoughby (125), Swanson and Moffatt (135) concluded that periodization was no more effective than traditional strength training for increasing muscular strength and girth size.

Training Volume

Although the term *training volume* is frequently used in the resistance-training literature, people who believe it is relevant to productive resistance training may interpret the term differently. From a conceptual standpoint, it may have little or no relevance to the efficacy of resistance-training protocols. Obviously, some undefined threshold of training volume must be attained to stimulate adaptations in muscular strength, hypertrophy, power, and endurance, but there is very little evidence to suggest that a specific volume of training differentially affects any of these outcomes. Using the exact formula for training volume noted by Willoughby (125, 130), where volume is equal to mass x repetitions per set x sets per session x sessions per week, the following hypothetical scenario demonstrates the lack of relevance, or perhaps the absurdity, in attempting to calculate the volume of exercise, or to compare different protocols based on training volume. If an individual performs one set of 10 RM bench presses with 100 kg 2x/wk, the weekly training volume is equal to 2,000 units (100 x 10 x 1 x 2). However, performing 10 sets of one repetition with 100 kg (the 10 RM) 2x/wk is 2,000 units (100 x 1 x 10 x 2), and 10 sets of 10 repetitions with 10 kg 2x/wk is also 2,000 units (10 x 10 x10 x 2). Based on the existing literature (discussed in other sections of this document), the first example would certainly be an adequate stimulus for adaptations in muscular strength, hypertrophy, power, and endurance, while the last two examples may generally be considered an inadequate stimulus; even though the training volume, as it is described by Willoughby (125, 130), is identical in the three hypothetical examples.

Contrary to the conclusion by Willoughby (124-125, 130) that “periodization” is superior to traditional resistance training, an alternative conclusion is that his studies suggest that a lower-volume resistance-training program (fewer sets) appears to be more effective in producing strength gains than the higher-volume protocols recommended throughout the Position Stand (3-6 sets of each exercise). This study (125,130) raises the question as to possible different outcomes in groups 1 and 2 had they also executed fewer sets throughout the study. Without such a comparison group, the claim by Willoughby (125,130) and in the Position Stand that “periodization” is an important component of a resistance-training program for optimal strength—is unsubstantiated.

The Position Stand claims that advanced resistance trainees have demonstrated a complex, cyclical pattern of training variation in order to optimize performance. Two references are cited (136-137) regarding that claim (p. 373). Hakkinen et al. (136) tested 13 male Finnish weightlifting champions and national record holders who had participated in weightlifting for approximately seven years. Every four months for a duration of one year they were evaluated for maximal bilateral isometric knee-extensor strength, Olympic lifts (snatch, clean and jerk), squat jump, countermovement jump, drop jump, integrated electromyography (IEMG) and fiber composition (muscle biopsies) of the vastus lateralis, as well as body mass, percent body fat, and thigh girth. Following the programs designed by their personal coaches, participants trained 5x/wk for competitive Olympic lifting. The exercises are described as the snatch, clean and jerk, various power lifts, pulling exercises, squat lifts, pressing exercises, and other strengthening exercises for selected muscle groups. No other information is provided regarding specific training protocols (repetition duration, range of repetitions, number of sets, intensity, etc.).

The only improvement was a significant increase (9 %) in squat jump performance (136). There was no significant change in the snatch lift, clean and jerk, isometric knee-extension torque, total mean fiber area, fast-twitch percentage, or mean areas of the fast-twitch and slow-twitch vastus lateralis. Body mass, percent body fat, and thigh girth did not change significantly. There was no significant improvement in countermovement jump, drop-jump performance, or maximal IEMG during the isometric knee extension, squat jump, countermovement jump, or drop-jump performance. Thus, only one of the 17 measured variables showed a significant change after one year of training. More importantly, Hakkinen et al. (136) did not compare different resistance-training protocols.

In the other study by Hakkinen et al. (137), which involved some of the participants from their previous study (136), they tested nine Finnish weightlifting champions and national record holders who had been training for a similar time of seven years. The training programs and testing intervals were similar to those described in their preceding study (136). After two years, there was a significant increase in the Olympic weightlifting total (2.8 %), thigh girth (1.3 %), and fat-free mass (2.0 %). There was no significant change in maximal isometric torque, maximum IEMG, force-time and IEMG-time curves, mean fiber area of either fast-twitch or slow-twitch fibers, total fiber area, or percentage of fast-twitch fibers (137).

In both of these studies by Hakkinen and colleagues (136-137) the resistance-training programs are not described in any detail, and they resulted in very few improvements in various outcomes. The casual reader of the Position Stand who does not scrutinize the methodology and results of the cited references, and their relevance to how they are being cited, may be unjustly impressed because of the noteworthy authors and the elite population of subjects. Most importantly, there is no comparison of one training program to another in either study. Therefore, neither reference (136-137) supports the superiority of one training program over another.

In summary, none of the aforementioned studies (118-125,136-137) cited in the Position Stand compared the so-called "periodization" protocols with single-set programs that simply varied the order or type of exercises to add some variety to the training. The Position Stand claims that the planned manipulation of program variables in advanced trainees can eliminate natural training plateaus and enable higher levels of muscular strength, hypertrophy, power, and local muscular endurance. That claim, which is central to the overall framework of the Position Stand, has very little supporting evidence (Table 8).

Table 8. Summary of Periodization Research.

Reference	Rating
Baker et al. (118)	↓
Hakkinen et al. (136)	↓
Hakkinen et al. (137)	↓
Herrick & Stone (119)	↓
O'Bryant et al. (121)	↑
Schiotz et al. (120)	↓
Stone et al. (122)	?
Stone et al. (123)	?
Swanson & Moffatt (135)	*
Willoughby (124)	?
Willoughby (125)	?

↑ Studies cited in the Position Stand that actually support the primary claim or recommendation.

? Studies cited in the Position Stand that support the primary claim or recommendation but contain serious flaws in the methodology or data.

↓ Studies cited in the Position Stand that fail to support the primary claim or recommendation.

* Studies not cited in the Position Stand that repudiate the primary claim or recommendation.

LOCAL MUSCULAR ENDURANCE

Local muscular endurance is defined in the Position Stand as *submaximal local muscular endurance* or *strength endurance* (p. 371). When it is reported as repetitions performed to fatigue with a given amount of resistance pre- and post-training, it is usually referred to as a test of "absolute muscular endurance". If the resistance is adjusted from a specific percent (e.g., 80 %) of the pre-training 1 RM to the same percent of the post-training 1 RM, it is usually referred to as "relative muscular endurance". Predictably, absolute muscular endurance should increase as a result of increased strength. However, the relationship between strength gains and absolute muscular endurance is not linear. For example, if a pre-training 1 RM is 100 kg and the maximal number of repetitions with 80 % 1 RM (80 kg) is 10, and the number of repetitions post-training increases 100 % to 20 with the same resistance (80 kg), the individual has become stronger and each repetition is therefore easier, but the person is not 100 % stronger. A 100 % increase in strength would require a 1 RM of 200 kg, or 10 repetitions with approximately 160 kg (80 % of the post-training 1 RM).

The Position Stand states that limited effects are observed in relative muscular endurance as a result of traditional resistance training (p. 371). One study (138) is cited. Mazzetti et al. (138) matched and randomly assigned 20 males (~24 years) to either a supervised or unsupervised resistance-training program. All the subjects had 1-2 years of resistance-training experience. Both groups performed the same resistance-training protocol of 3 x 12 RM wk 1-2, 3 x 8-10 RM wk 3-6, 3-4 x 6-8 RM wk 7-10, 2-3 x 3-6 RM wk 11-12 using identical equipment (free weights and machines) 3-4x/wk (~8 exercises per session) for 12 weeks. There was a significant increase in 1 RM squat (33 and 25 %) and bench press (22 and 15 %), supervised and unsupervised groups, respectively, with the gains in strength significantly greater for the supervised group. Baseline relative muscular endurance for the free-weight bench press exercise was reported as the number of repetitions performed to fatigue using 80 % of the pre-training 1 RM. After 12 weeks, the resistance for the relative endurance test was increased to 80 % of the post-training 1 RM (33 and 25 % for the squat, and 22 and 15 % for the bench press, supervised and unsupervised groups, respectively). The number of repetitions to fatigue (~7) was similar in both groups pre-training, and remained unchanged post-training (~7). Mazzetti et al. (138) concluded that relative muscular endurance was not compromised (no significant change) as a result of the resistance training.

It should be recognized that the results of Mazzetti et al. (138) could be interpreted in different ways. That is, the relative muscular endurance (maximal number of repetitions with a specific percent of 1 RM) does not appear to change with training—and there is very little evidence to suggest that it should. Or, that the performance of relative muscular endurance increases by the amount of resistance required to equal 80 % of the post-training 1 RM. The former interpretation renders the aforementioned statement in the Position Stand irrelevant; the latter is a contradiction to that statement.

A resistance-training study by Hickson et al. (139) confirmed the validity of both the aforementioned interpretations. Hickson et al. (139) trained eight previously untrained males and females (~28 years) 3x/wk for 16 weeks. Subjects performed five sets of five repetitions with 80 % 1 RM for the free-weight bench press and squat exercises, and 3 x 5 RM for the knee-extension, knee-flexion and elbow-extension exercises on machines, with two minutes rest between sets. The 1 RM and the maximal number of repetitions performed at 40, 60, and 80 % 1 RM for the bench press and squat exercises were tested pre- and post-training. Subjects were tested post-training at the same absolute pre-training resistance. They were also tested post-training with a new adjusted resistance based on the new post-training 1 RM. There was a significant increase in 1 RM bench press (23 %) and squat (37 %). The absolute endurance for the bench press significantly increased ten, eight, and eight repetitions at 40, 60, and 80 % 1 RM, respectively. Similarly, the absolute endurance for the squat significantly increased 25, 17, and 12 repetitions at 40, 60, and 80 % 1 RM, respectively. However, when retested at the same relative intensity (adjusted to post-training 1 RM), the number of repetitions was similar to pre-training for the bench press (~39, 17, and 7) and the squat (~53, 22, and 9) at 40, 60, and 80 % 1 RM, respectively. Hickson et al. (139) concluded that relative muscular endurance remains unchanged following resistance-training induced strength gains. Or, one could conclude that because the resistance for the post-training relative endurance test was increased 23 % for the bench press and 37 % for the squat, the subjects enhanced performance of relative muscular endurance in the bench press and squat by 23 and 37 %, respectively.

The Position Stand claims that lighter resistance coupled with a greater number of repetitions (>20) have been shown to be most effective for enhancing muscular endurance (p. 372), and two studies (140-141) are cited.

Anderson and Kearney (140) randomly assigned 43 previously untrained (described as unable to bench press 120 % of their body mass) males (~21 years) to perform the bench press exercise 3x/wk for nine weeks using one of three training protocols: 3 x 6-8 RM, 2 x 30-40 RM, or 1 x 100-150 RM (low, medium and high-repetition groups, respectively). The maximum number of repetitions with 40 % of the 1 RM was used to test relative muscular endurance, and 27.23 kg was the mass used pre- and post-training to test absolute muscular endurance. The increase in 1 RM bench press for the low-repetition group (~20 %) was significantly greater than the medium (~8 %) and high (~5 %) repetition groups. There was a significant increase in absolute muscular endurance for the low, medium and high-repetition groups, respectively (~24, 39, and 41 %) with no significant difference among the groups. The medium- and high-repetition groups significantly increased their relative endurance (~22 and 28 %, respectively). The claim in their Abstract (p. 1) that there was a decrease in relative endurance in the low-repetition group is not supported by their data. That is, there was no significant change in the low-repetition group. Anderson and Kearney (140) noted that the lack of a significant change in relative endurance for the low-repetition group must be viewed in light of the fact that their maximal strength increased by 20 %, and thus the resistance used for the relative endurance also increased 20 %.

The Position Stand also cites Anderson and Kearney (140) as evidence to suggest that to increase local muscular endurance one should minimize recovery between sets (p. 372). Anderson and Kearney (140) assigned two minutes rest between each of two sets for their high-resistance and medium-resistance groups. There was no comparison of different rest times between groups because both groups rested the same time between sets, and the low-resistance group performed only one set. Anderson and Kearney (140) reported no data relative to different rest time between sets. Therefore, their study (140) does not support the claim in the Position Stand.

Stone and Coulter (141) randomly assigned 50 previously untrained females (~23 years) to perform 3 x 6-8 RM, 2 x 15-20 RM, or 1 x 30-40 RM for each of five exercises (bench press, squat, triceps pushdown, biceps curl, and lat pull) 3x/wk for nine weeks. Strength (1 RM) and muscular endurance for the free-weight bench press and squat were reported. In one test for absolute muscular endurance the subjects used 15.9 kg in the bench press and 25 kg in the squat for both the pre- and post-training assessments. Stone and Coulter (141) claimed that muscular endurance in the bench press (45 % 1 RM) and squat (55 % 1 RM) was also tested with Load 1, which was based on the pretest 1 RM, and Load 2 based on posttest 1 RM. Because it would be difficult to establish the resistance for Load 1 before actually testing the 1 RM, we assume that Stone and Coulter (141) are referring to the pre-training and post-training 1 RMs. The authors also claimed that Load 2 was based on the post-training 1 RM. However, pre-training and post-training data were reported for Load 2 in their Table 1 (p. 233). The absence of a more specific description of the testing procedure renders the exact nature of the Load 2 dependent variables unknown. However, we assume that for this test of muscular endurance the resistance for the post-training test was adjusted to either 45 or 55 % of the new post-training 1 RM. Therefore, this was the only true test of relative muscular endurance.

In their Methods section (p. 232), Stone and Coulter (141) claimed that all 50 subjects completed the entire training program. However, in their Discussion section (p. 233), Stone and Coulter (141) claimed that their dropout rate of 42 % in nine weeks was higher than normally reported in supervised exercise programs; a discrepancy in reporting at best. There are asterisks next to five of the values reported by Stone and Coulter (141) in their Table 1 (p.233). However, there is no description in the legend or the narrative of what the asterisks represent.

The three training programs produced a significant increase in 1 RM bench press (18.9, 16.7, and 11.6 %) and squat (33.0, 30.9, and 25.1 %), low, medium, and high-repetition groups, respectively, with no significant difference in strength gains among the groups for either exercise (141). In their Abstract (p. 231) Stone and Coulter (141) claimed that the low-repetition high-resistance protocol produced greater gains in strength, and in their Practical Applications section (p. 234) they claimed that the strength-training professional must rely on low-repetition high-resistance training to maximize strength. However, their own descriptive data (Table 1, p.233) and statistical analyses (Table 2, p. 233) fail to support these claims.

Absolute muscular endurance for the bench press with the pre-training resistance (15.9 kg) increased significantly in the low-repetition (31.0 %) and medium-repetition group (41.2 %). Absolute endurance for the squat with 25 kg significantly increased in the low-repetition (84.3 %) and high-repetition group (80.1 %). However, there was no significant difference in the post-training gains in absolute muscular endurance among the three groups for either exercise (141). Absolute muscular endurance (described by Stone and Coulter (141) as "Relative Endurance Load 1") that was based on 45 % of the pre-training 1 RM bench press and 55 % of the pre-training 1 RM squat significantly increased for the low-repetition (24.8 %) and high-repetition group (30.4 %) in the bench press, and 65.9 and 82.6 % in the squat for the low-repetition and high-repetition groups, respectively. There was no significant difference among the three groups for either exercise. In addition, there was no significant change in the only true measure of relative muscular endurance for any of the groups in either the bench press or squat, as assessed by what Stone and Coulter (141) described as "Relative Endurance Load 2".

Contrary to their claim in the Discussion section (p. 233) that there was a 6.9 % loss of relative muscular endurance for the high-resistance low-repetition group, Stone and Coulter (141) reported that the pre- to post-training difference of three repetitions in this group was not statistically significant (Table 1, p. 233). Regardless of how the muscular endurance tests were defined or how they are interpreted, Stone and Coulter (141) stated in their Results section that there were no significant post-training differences among the three training programs (low, medium, and high-repetition groups) in strength, absolute endurance, or relative endurance in Loads 1 and 2. In fact, contrary to their conclusion that the statistical results do not unequivocally support a strength/endurance continuum of strength training, they actually reported no evidence to support their conclusion.

In summary, the claim in the Position Stand that a greater number of repetitions are more effective for enhancing muscular endurance is not supported by the results reported by Stone and Coulter (141).

The Position Stand claims that moderate- to low-resistance training coupled with a high number of repetitions has been shown to be most effective for improving absolute and relative local muscular endurance (p. 371). Two studies (140, 142) are cited in an attempt to support the claim. The study by Anderson and Kearney (140) was previously discussed. Huczel and Clarke (142) measured muscular strength and absolute muscular endurance in 30 untrained and resistance trained females (18-34 years), and concluded that that the resistance-trained females were stronger and had greater muscular endurance than untrained females. There was no comparison of different training protocols, and no report on the resistance-training program for the previously trained females. More importantly, this was not a longitudinal resistance-training study (142). Therefore, it does not support the claim in the Position Stand.

The Position Stand claims that high-volume programs have been shown to be superior for enhancing muscular endurance**,** although it is not stated whether this refers to absolute or relative endurance (p. 372). Four studies (34-35, 139, 143) are cited in an attempt to support this claim. The study by Hickson et al. (139), which was previously discussed, does not support the claim in the Position Stand.

Two of the previously discussed Experiments #2 and #4 by Kraemer (35) involved male (~20 years) American football players. In Experiment #2, 40 Division I players performed either one set or three sets of 8-12 RM for each of 10 exercises 3x/wk for 10 weeks. The number of repetitions with 80 % 1 RM for the bench press and 85 % 1 RM leg press were assessed pre- and post-training. There was no significant change in relative muscular endurance for either exercise in the 1-set group. The 3-set group significantly increased relative muscular endurance 32.2 % in the bench press and 35.7 % in the leg press. In Experiment #4, 44 Division III players performed either one set of 8-12 RM for each of approximately 10 exercises 3x/wk for 24 weeks, or 2-4 sets of either 3-5, 8-10, or 12-15 RM for each of approximately 10 exercises 4x/wk for 24 weeks. There was a similar rest time between sets (1-2 minutes) for both groups. Relative muscular endurance tests at 80 % 1 RM for the bench press and 85 % 1 RM leg press were assessed pre- and post-training. There was a significant increase in relative muscular endurance in the bench press (37.6 and 56.2 %) and leg press (22.5 and 41.3 %), single-set and multiple-set groups, respectively, with the increase significantly greater for the multiple-set group. In other words, the number of repetitions significantly increased in spite of the increase in resistance, which was based on the post-training 1 RM. These remarkable changes in relative muscular endurance reported by Kraemer (35) in both Experiment #2 and Experiment #4 are unlike those in any of the other cited studies.

Marx et al. (34) randomly assigned 34 previously untrained females (~23 years) to single-set or multiple-set resistance training for six months. The single-set group performed one set of 8-12 RM for each exercise on two alternating circuits of 10 machine exercises 3x/wk. The multiple-set group trained 4x/wk and performed 2-4 sets of 8-10 RM on Tuesday and Friday, and 3-5 RM, 8-10 RM, or 12-15 RM on Monday and Thursday, using 7-12 free-weight and machine exercises. Muscular endurance was measured for the bench press and leg-press exercises using 80 % 1 RM. Bench press endurance significantly increased for the single-set (1 repetition) and multiple-set (2.3 repetitions) groups, and leg-press endurance significantly increased for the single-set (2.1 repetitions) and multiple-set (7.3 repetitions) groups, with the multiple-set group significantly greater than the single-set group in both exercises. Marx et al. (34) did not report an adjustment in the resistance based on the post-training 1 RM. Therefore, readers do not know if the data for muscular endurance was absolute or relative.

McGee et al. (143) assigned 29 males (17-26 years), who were involved in a college weight-training class (resistance training experience not described), to perform the squat exercise 3x/wk for seven weeks using one of three protocols: 1 x 8-12 RM, 3 x 10, or 3 x 10 wk 1-2, 3 x 5 wk 3-5, 3 x 3 wk 6-7. Maximal mass lifted in the squat exercise increased pre- to post-training by 6, 7, and 9 %, 1-set, 3-set, and varied multiple-set groups, respectively, with the 7 and 9 % increase statistically significant. There was no significant difference among the groups. A greater number of repetitions post-training (11, 15, and 17, respectively) were reported for the three groups, but the increase of 11 repetitions was not statistically significant. However, McGee et al. (143) noted that there was no significant difference among the groups in any post-training outcome.

The Position Stand claims that the duration of rest intervals between sets and exercises (1-2 min rest between sets of 15-20 repetitions, and less than 1 min rest between sets of 10-15 repetitions) affects muscular endurance, and that bodybuilders who typically train with high volume and short rest periods demonstrate a lower fatigue rate compared with power-lifters who typically train with low to moderate volume and longer rest periods between sets and exercises (p. 372). A study by Kraemer et al. (144) is cited in an attempt to support the superiority of high-volume resistance training with shorter rest periods.

Kraemer et al. (144) matched nine male bodybuilders and eight power-lifters (~22 years) who had been involved in competitive lifting from 4-6 years. Resistance training was monitored for six months prior to the study. The training sessions prior to this study (144) were characterized as sets of 6-12 RM with 10-90 seconds rest for the bodybuilders, and 1-8 RM with 120-420 seconds rest between sets and exercises for the power-lifters. The experimental session involved the performance of three sets of 10 RM for each of 10 free-weight and machine exercises, with 10 seconds rest between sets and alternating 30 and 60 seconds rest between exercises. Results showed that the only significant differences during the exercise session were that the power-lifting group exhibited a significantly greater incidence of dizziness and nausea compared with the bodybuilders. The power-lifters were significantly stronger than the bodybuilders in the bench press and leg press, but they used a lower percent of their 1 RM to perform the exercises. However, there was no significant difference between groups in the total amount of work (described as resistance x vertical displacement) performed during the session. Heart rate, plasma volume, lactic acid, epinephrine, norepinephrine, dopamine, and rating of perceived exertion significantly increased pre- to post-exercise in both groups, with no significant difference between groups. The results of this study (144), and specifically the absence of any report of muscular endurance or fatigue rate, render the claim in the Position Stand unfounded.

Although not stated in the Position Stand, the research strongly suggests that relative muscular endurance varies with different exercises (132-133), and that the relationship between muscular strength and local relative muscular endurance does not appear to change as a result of resistance training (145). Hoeger et al. (132) reported the maximal number of repetitions performed in 38 untrained males (~35 years) on seven different free-weight and machine exercises using 40, 60, and 80 % 1 RM. There was a significant difference in the maximal number of repetitions with different exercises. For example, the subjects performed an average of 9.8 repetitions in the bench press and 15.2 repetitions in the leg press, using 80 % 1 RM for both trials. Hoeger et al. (132) concluded that the maximal number of repetitions performed at selected percentages of the 1 RM is not the same for all exercises.

Hoeger et al. (133) evaluated 25 resistance-trained males (~29 years), 40 untrained females (~37 years), and 26 trained females (~24 years). The experience in the resistance-trained subjects ranged from two months to four years. Hoeger et al. (133) also included data for untrained males from their previous investigation (132). The maximal number of repetitions was recorded on seven free-weight and machine exercises at 40, 60, and 80 % 1 RM. Hoeger et al. (133) reported a significant difference in the maximal number of repetitions among the seven exercises. For example, 12.2 repetitions in the bench press and 19.4 in the leg press at 80 % 1 RM. Although this was a cross-sectional comparison of different groups, and some of the exercises showed a significant difference in the maximal number of repetitions between the resistance-trained and untrained males, there was no significant difference in the bench press or leg press exercises at 80 % 1 RM. Hoeger et al. (133) concluded that when comparing trained and untrained males, there was no significant difference in the maximal number of repetitions performed at a specific percent of 1 RM.

Mayhew et al. (145) trained 70 males (~20 years) and 101 females (~20 years) in a college fitness class 3x/wk for 14 weeks. Subjects performed free weight and machine exercises for the chest, arms, back, abdomen, and lower body using a 5-12 RM (number of sets not reported). There was a significant increase in the 1 RM free-weight bench press for males (13.7 %) and females (25.9 %). With the same percent of 1 RM pre-and post-training (~77 %), and a resistance adjusted to post-training 1 RM (+13.7 % and 25.9 %, males and females, respectively), the number of maximal repetitions was similar pre- and post-training in males (10.8 and 11.0 repetitions, pre- and post-training, respectively) and females (12.4 and 12.6 repetitions, pre- and post-training, respectively). Mayhew et al. (145) concluded that there was no change in the relationship between strength and relative muscular endurance as a result of resistance training, and that the maximal number of repetitions can be used to assess improvements in strength (1 RM).

These studies (132-133, 139, 145) illustrate the dominant role played by genetic factors. That is, although the relationship between 1 RM and relative muscular endurance may differ among people and among exercises

Table 9. Summary of Local Muscular Endurance Research.

Reference	Rating
Anderson & Kearney (140)	?
Hickson et al. (139)	↓
Hoeger et al. (132)	∗
Hoeger et al. (133)	∗
Huczel & Clarke (142)	↓
Kraemer (35)	?
Kraemer et al. (144)	↓
Marx et al. (34)	?
Mayhew et al. (145)	∗
Mazzetti et al. (138)	?
McGee et al. (143)	↓
Stone & Coulter (141)	↓

↑ Studies cited in the Position Stand that actually support the primary claim or recommendation.

? Studies cited in the Position Stand that support the primary claim or recommendation but contain serious flaws in the methodology or data.

↓ Studies cited in the Position Stand that fail to support the primary claim or recommendation.

∗ Studies not cited in the Position Stand that repudiate the primary claim or recommendation.

within an individual (132-133), increased strength does not appear to significantly affect this relationship (139, 145).

In summary, any reasonable range of repetitions (e.g., 3-6 RM, 8-10 RM, 12-15 RM) will enhance muscular strength and absolute muscular endurance. As measured by the number of repetitions performed with a specific percent of pre-training and adjusted post-training 1 RM, there is very little evidence, either theoretically or empirically, that relative muscular endurance changes as a result of resistance training (Table 9), unless the increase in post-training resistance is considered.

POWER

For advanced power training the Position Stand recommends a varied multiple-set (3-6 sets) power protocol consisting of 1-6 repetitions, which they claim should be integrated into a resistance-training program (p. 371). There is no reference that supports this recommendation.

The Position Stand claims that heavy resistance training may actually decrease power output unless explosive movements are also performed, and one study (146) is cited (p. 371). Bobbert and Van Soest (146) conducted a simulated investigation of vertical jumps, with muscle stimulation as input and movement dynamics as output. This was not a training study. Bobbert and Van Soest (146) noted that the conclusions of their study were hypotheses. Therefore, the study (146) does not support the claim in the Position Stand.

The Position Stand claims that a program consisting of movements with high power outputs and relatively light loads are more effective for improving vertical jump than traditional resistance training (p. 371). Two references (147-148) are cited. Hakkinen and Komi (147) trained eleven males (~25 years) who had earlier experience with resistance training (not specified) 3x/wk for 24 weeks. Subjects performed the barbell squat for 1-10 repetitions per set using 70-100 % 1 RM for a total of 18-30 repetitions at each session. During the 3rd, 5th, and 6th training months, they also performed 3-5 eccentric-only squats with 100-120 % 1 RM. The resistance training produced a significant increase in 1 RM squat (30.2 %) and vertical jump (7.3 %). In a follow-up study, Hakkinen and Komi (148) trained ten males (~27 years), who were accustomed to resistance training, 3x/wk for 24 weeks. With a maximal effort, the subjects executed five different types of jumping exercises for a total of 100-200 jumps per session. Jump training produced a significant increase in 1 RM squat (6.9 %) and vertical jump (21.2 %).

Not surprisingly, the group in the second study by Hakkinen and Komi (148) who practiced jumping for 24 weeks (7,200-14,400 jumps) had a greater increase in vertical jump than the group from the previous study (147) that did not practice jumping. However, Hakkinen and Komi (147-148) did not randomly assign subjects to either a resistance-training or jump-training group, nor did they statistically compare one training group with the other. Each training group was compared with a control group. The absence of a statistical comparison of jump training with traditional resistance training in either study (147-148) renders the claim in the Position Stand unsubstantiated.

The Position Stand claims that loaded jump squats with 30 % 1 RM have been shown to increase vertical jump height more than traditional back squats and plyometrics (p. 371). In one of the references cited, Wilson et al. (149) randomly assigned 64 subjects (~23 years), who were currently weight training for at least one year, to one of four groups: traditional resistance training consisting of 3-6 sets of 6-10 RM squat exercise, depth-jump training (plyometric group), 3-6 sets of explosive resistance training (loaded jump squats) with 30 % of maximal isometric force (max power group), or no training. After training 2x/wk for 10 weeks there was a significantly greater increase in vertical jump (14.8 %) and countermovement jump (17.6 %) in the group who performed 3-6 sets of weighted jump squats (max power group). None of the groups significantly increased the rate of force development or decreased 30-meter sprint time. The traditional (6.5 %) and max-power group (5.2

%) significantly increased peak power for the 6-second cycle test—perhaps the only true power measurement reported—with no significant difference between groups. The max-power group was the only group to significantly increase isokinetic (5.2 rad/s) peak torque (7.0 %). However, the data presented raises the question of why the increase in peak torque for the traditional group (8.7 %), with a smaller standard deviation both pre- and post-training and a greater number of subjects (n = 15) compared with the max-power group (n =13), did not show a statistically significant difference. The traditional group produced a significant increase in vertical jump (6.8 %) and countermovement jumps (5.1 %). The traditional weight-training group was the only group to significantly increase maximal knee-extension force (14.4 %). The results of this study by Wilson et al. (149) actually show that with the exception of the questionable difference in isokinetic knee-extension torque, the only significantly greater increases in the max-power group were the jump movements; perhaps simply because the subjects practiced jumping for 10 weeks.

In a later study by Wilson et al. (150), 45 males (~23 years), who were weight training for at least one year, were randomly allocated to one of three groups: traditional resistance training, plyometric training, or control. The resistance-training group performed 3-6 sets of 6-10 RM squats and bench presses, and the plyometric group executed 3-6 sets of 6-10 depth jumps (20-70 cm) and medicine-ball throws (4-10 kg). Both groups trained 2x/wk for 8 weeks. The resistance-training group significantly increased 1 RM squat (20.9 %), counter-movement jump (21.2 %), isoinertial jump height with 50 % body mass (6.1 %), 1 RM bench press (12.4 %), average force in the push-up (6.8 %), isoinertial bench-press throw (8.4 %), and upper-body rate of force development (15.5 %). The plyometric group significantly increased lower-body rate of force development (27.5 %), counter-movement jump (18.1 %), and average force in the push-up (8.0 %). The resistance-training group significantly increased in seven out of 14 tested variables, while the plyometric group significantly gained in only three out of 14 variables. Most notably, there was no significant difference in the increase in counter-movement jump between groups. This study by Wilson et al. (150) was not cited in the Position Stand.

It appears that resistance training coupled with practice of the specific skill to be enhanced (such as jumping) is all that is required to enhance that specific activity. For example, Clutch et al. (151) randomly assigned 16 males from a weight-training class and 16 males from a volleyball team (~21 years) to either a resistance-training program with no depth jumping or a program of resistance training and depth jumping. Resistance training consisted of 3 x 6 RM for the squat, bench press, and dead-lift exercises. The depth-jump protocol required performing four sets of ten depth jumps from heights of 0.75-1.10 meters. The groups trained 2x/wk for 16 weeks. Three of the four groups significantly increased vertical jump height: resistance trainees who performed resistance training and depth-jump training (3.73 cm), volleyball players who performed resistance training (4.25 cm), and volleyball players who performed resistance training and depth jumps (3.21 cm), with no significant difference among the three groups. The volleyball players who performed resistance training had similar gains in vertical jump as the volleyball players who performed resistance training and depth jumping exercises. The group in the weight-training class that performed resistance training and did no jumping was the only group to show no significant improvement in vertical jump. Clutch et al. (151) concluded that a program of depth jumping adds nothing to a program that already includes resistance training and other jumping movements, such as those inherent in volleyball.

Two references are cited in the Position Stand (p. 371) in an attempt to support the claim that loaded jump squats with 30 % 1 RM have been shown to increase vertical jump performance. One is a study by Kaneko et al. (152), and the other is the previously discussed study by Moss et al. (15). There was no report of vertical jump performance in either of these studies, perhaps because the subjects trained the elbow flexors. Therefore, these studies (15, 152) fail to substantiate the claim in the Position Stand.

The Position Stand recommends inclusion of total-body exercises such as the power-clean and push-press exercises for developing muscular power, and claims that these exercises have been shown to require rapid force production. The Position Stand also claims that the quality of effort for each repetition, which is defined in the Position Stand as maximal velocity, is critical to the performance of these exercises (p. 371). A study by Garhammer and Gregor (153) is cited. Garhammer and Gregor (153) tested the vertical force-time of four male Olympic weightlifters performing snatch lifts on a force plate and compared the results to nine male athletes (including three Olympic lifters), who also executed vertical jumps on the force plate. The power clean and the push-press exercises were not used in this investigation (153), and it was not a training study. That is, Garhammer and Gregor (153) compared the acute exercise responses, and not specific chronic adaptations to resistance training. Therefore, the study (153) does not support the recommendation in the Position Stand.

It should be noted that based on mechanical physics, the vertical jump and counter-movement jumps are not actually indices of power because force and time are not typically measured. The jumps may simply be measures of some specific functional performance tasks. Furthermore, none of the aforementioned studies has shown any carry-over from an increase in jump height to any other physical activity.

If ground reaction forces and time are measured on a force platform during a jump, power can be estimated. For example, Holcomb et al. (154) randomly assigned 51 previously untrained college-age males to one of four training groups (resistance training, counter-movement jump, plyometric, modified plyometric) or a control group. The resistance-training group performed three sets of 8 RM (wk 1-3), 6 RM (wk 4-6) and 4 RM (wk 7-8) knee-flexion, knee-extension, plantar-flexion and leg-press exercises. The counter-movement jump, plyometric, and modified plyometric groups executed nine sets of eight repetitions for the counter-movement jump, depth jumps (40-60 m, wk 1-8), and three different types of depth jumps, respectively. The groups trained 3x/wk for eight weeks. Vertical jump and counter-movement jump were measured on a force platform, and the ground reaction forces were used to estimate power and jump height. The four training groups (resistance, counter-movement, plyometric, and modified plyometric, respectively) significantly increased vertical jump height (10.5, 7.9, 12.2, 11.0 %) and estimated peak power (3.1, 2.5, 7.4, 6.8 %), counter-movement jump (7.3, 9.5, 12.3, 9.3 %) and estimated peak power (4.7, 4.0, 6.5, 4.5 %). Holcomb et al. (154) concluded that no one method of training was superior to another for increasing jump height or power performance. This study (154) was not cited in the Position Stand.

The Position Stand first notes the importance of resistance training for sport-specific activities, and in the next sentence stresses the importance of strength and ballistic resistance training for sport-specific activities such as throwing velocity. There are five references cited (155-159) in an attempt to support that claim (p. 373). Fleck et al. (155) reported correlations between peak concentric isokinetic torque and throwing velocity. They recommended a resistance-training program to increase concentric torque capability of the muscles involved in shoulder extension, internal rotation, horizontal abduction and adduction, and elbow flexion and extension. There was no reference to ballistic training, and more importantly, this was not a training study (155).

Hoff and Almasbakk (156), Lachowetz et al. (157), and McEvoy and Newton (158) compared ballistic resistance training with control groups. There was no comparison of the ballistic programs with traditional resistance training.

Only one (159) of these five references (155-159) cited in the Position Stand compared traditional resistance training with ballistic training. Newton and McEvoy (159) randomly assigned 24 previously untrained male Australian National League baseball players (~19 years) to eight weeks of resistance training, ballistic medicine ball throwing, or normal baseball throwing (control group). The resistance-training group performed 3 x 8-10 RM wk 1-4 and 3 x 6-8 RM wk 5-8 in the barbell bench press and pullover exercises. They were instructed to perform the lifts using what the authors describe as relatively slow, controlled movements. The medicine-ball group performed three sets of eight repetitions wk 1-4 and three sets of ten repetitions wk 5-8 of maximal effort, explosive chest press and overhead throws with a 3 kg medicine ball. Both experimental groups trained 2x/wk and all the groups participated in normal baseball practice 2x/wk. The medicine-ball group significantly increased 6 RM free-weight bench press (8.9 %), but it was not significantly greater than the control group (3.4

%, n.s.). The resistance-training group significantly increased bench press strength (22.8 %), which was significantly greater than the medicine-ball group and the control group. The resistance-training group was the only group to increase maximal throwing velocity (4.1 %). Newton and McEvoy (159) concluded that conventional free-weight resistance training significantly improved strength and throwing velocity more than the group that trained explosively with medicine balls.

Four of the five studies cited in the Position Stand regarding throwing velocity do not support their statement (155-158), and one study (159) contradicts their statement, thereby rendering the claim in the Position Stand unsubstantiated.

The Position Stand claims that an increase in power enables older adults to improve performance in activities requiring a rapid rate of force development, and that there is support for resistance training specific for power development in healthy older adults (p. 373). Five references (160-164) are cited in an attempt to support that claim. Bassey et al. (160) reported correlations of knee-extension power and functional performance in elderly males (~89 years) and females (~87 years). They concluded that measurement of knee-extension power in frail elderly people could be useful in selecting effective rehabilitation programs. However, this was not a training study.

Table 10. Summary of Muscular Power Research.

Reference	Rating
Bassey et al. (160)	↓
Bobbert & Van Soest (146)	↓
Clutch et al. (151)	↑
Fleck et al. (155)	↓
Garhammer & Gregor (153)	↓
Hakkinen & Hakkinen (161)	↓
Hakkinen & Komi (147)	?
Hakkinen & Komi (148)	?
Hakkinen et al. (162)	↓
Hakkinen et al. (163)	↓
Hoff & Almasbakk (156)	↓
Holcomb et al. (154)	*
Kaneko et al. (152)	↓
Kraemer et al. (164)	↓
Lachowetz et al. (157)	↓
McEvoy & Newton (158)	↓
Moss et al. (15)	↓
Newton & McEvoy (159)	↓
Wilson et al. (149)	?
Wilson et al. (150)	*

↑ Studies cited in the Position Stand that actually support the primary claim or recommendation.

? Studies cited in the Position Stand that support the primary claim or recommendation but contain serious flaws in the methodology or data.

↓ Studies cited in the Position Stand that fail to support the primary claim or recommendation.

* Studies not cited in the Position Stand that repudiate the primary claim or recommendation.

Hakkinen and Hakkinen (161) reported maximal knee-extension force, force-time curves, rate of force development, relaxation-time curves, electromyographic activity, quadriceps cross-sectional area, body mass, and percent body fat after 12 weeks of combined heavy resistance and explosive training in middle-aged (43-57 years) and older (64-73 years) males and females. Only one training protocol was used in this study. There was no comparison of resistance training specific for power development versus non-explosive resistance training.

Hakkinen et al. (162) compared 12 weeks of unilateral or bilateral knee-extension heavy resistance training in middle-aged (43-57 years) and older (59-75 years) males and females. There was no description of any type of explosive, ballistic, or power-development program, and no measurement of power was reported.

Hakkinen et al. (163) reported maximal knee-extension and knee-flexion isometric force, rate of force development, force-time curves, cross-sectional area, and electromyographic activity, body mass and percent body fat after six months of combined heavy resistance and explosive training in middle-aged (~41 years) and elderly (~70 years) males and females. There was only one training protocol used in this study, and consequently, no comparison of non-explosive versus explosive resistance training.

Kraemer et al. (164) reported the hormonal responses in younger (~30 years) and older (~62 years) males after 10 weeks of strength-power training. There was no comparative training protocol and no power measurement reported.

None of these studies (160-164) cited in the Position Stand compared traditional resistance training with explosive power training in younger, middle-aged, or older subjects, and none of the four training studies (161-164) reported measures of functional performance. Therefore, the claim in the Position Stand that resistance training in older populations should be specific for power development, as compared with slower, non-explosive resistance training, is not supported with any comparative resistance-training studies.

In summary, there is very little evidence cited in the Position Stand to support the claim that explosive, multiple-set protocols are required to enhance the ability to produce power (Table 10), or enhance specific sport skills or functional ability. Some of the citations in the Position Stand (15, 152, 155, 160) are entirely irrelevant to the claims.

MUSCULAR HYPERTROPHY

The Position Stand recommends high-volume resistance training for maximal muscle hypertrophy (p. 370). A study by McCall et al. (165) is cited to show that acute resistance exercise-induced increases in growth hormone concentration are highly correlated with the magnitude of muscle hypertrophy.

McCall et al. (165) trained 11 males (18-25 years), with recreational resistance training experience, 3x/wk for 12 weeks. Subjects performed three sets of 10 RM for each of eight free weight and machine exercises, four of which primarily involved the elbow flexors. They were instructed to lift to concentric fatigue for each set, with 1-minute rest between sets and exercises. Elbow flexion strength (25 %), and biceps brachii elbow flexor cross-sectional area (12.7 %) significantly increased. There was no significant difference in resting hormone concentrations (growth hormone, testosterone, insulin-like growth factor-I, and sex hormone-binding globulin) pre- to post-training, except for a significant decrease in cortisol. McCall et al. (165) claimed that the decrease in resting cortisol concentration was 16.7 % in the training group and a control group, which comprised eight males (19-29 years) who did not participate in resistance training. However, the data in their Table 1 (p. 101) show a decrease of 22.0 % for the training group and 8.4 % for the control group. Resting hormone concentrations of growth hormone, IGF-I, testosterone and sex hormone-binding globulin were not significantly correlated with either total biceps brachii hypertrophy or muscle fiber hypertrophy.

After correcting for exercise-induced changes in plasma volume, there was no significant exercise-induced change in IGF-I, testosterone, or sex hormone-binding globulin (165). There was a significant correlation of acute exercised-induced growth hormone increase and the relative degree of type I ($r = 0.74$) and type II ($r = 0.71$) biceps brachii fiber hypertrophy. However, there was no significant correlation between acute exercised induced changes of the other hormones and the indices of muscular strength or hypertrophy. McCall et al. (165) concluded that only the acute exercise-induced growth hormone elevations were correlated with the magnitude of muscle fiber hypertrophy following training. In reporting additional results from this study (165), McCall et al. (166) noted that there was no correlation between the increase in biceps brachii cross-sectional area and type I ($r = 0.197$), type II ($r = 0.353$) or mean ($r = 0.191$) muscle fiber area. They concluded that the overall muscle hypertrophy was not related to the magnitude of muscle fiber hypertrophy (166).

More importantly, McCall et al. (165) did not compare adaptations or hormonal responses to a lower-volume group; that is, there was no comparison to a group performing fewer exercises per muscle group and fewer sets per exercise. In an attempt to support a high-volume training philosophy, the authors of the Position Stand apparently selected one piece of information from the study by McCall et al. (165) and neglected to report the other results, almost all the results, from this study that did not support the opinion in the Position Stand.

The Position Stand claims that the types of protein synthesized may have a direct impact on various designs of resistance training programs; for example, body building compared with strength training (p. 369). The Position Stand also claims that the total work involved with traditional strength training may not maximize hypertrophy (p. 370). No resistance-training studies are cited. The only reference cited to support both claims is a book by Zatsiorsky (108). There are no references cited in Zatsiorsky's book to support his opinions, or the opinions in the Position Stand.

The Position Stand recommends 3-6 sets of each exercise to increase muscle hypertrophy in advanced trainees (p. 370). No references are cited to substantiate this volume of training. Contrary to this unsupported recommendation, the previously discussed study by Ostrowski et al. (53) is especially noteworthy because the training program encompassed the modality and protocols recommended in the Position Stand, and the subjects were currently weight training for 1-4 years. The subjects performed free-weight exercises and followed a split routine (2 days upper body and 2 days lower body each week) for 10 weeks. The only difference in training variables among the three programs was the number of sets (1, 2, or 4 sets of each exercise), with all sets performed to muscular fatigue and 3-minutes rest between sets. Ostrowski et al. (53) concluded that the results demonstrated that low, moderate, and high volume protocols showed no significant difference in their effect on body mass, upper-body and lower-body muscular strength, power, and hypertrophy (rectus femoris hypertrophy and triceps brachia thickness) over the 10-week training period in resistance-trained males.

The Position Stand claims that programs for enhancing muscular hypertrophy require moderate to very heavy loads and high volume (p. 370). A book chapter by Kraemer (167) is the only reference cited.

The Position Stand claims that greater muscular hypertrophy in resistance-trained individuals is associated with high-volume, multiple-set programs compared with low-volume, single-set programs (p. 370), and three references (34-35, 37) are cited. The remarkable results from the Experiments by Kraemer (35) are discussed in our Multiple Sets section. Contrary to the claim in the Position Stand, the studies by Kraemer et al. (37) and Marx et al. (34) involved previously untrained participants.

The Position Stand claims that the amount of work and force are associated with gains in muscular hypertrophy (p. 370). Three references (15, 168-169) are cited in an attempt to support that belief. The study by Moss et al. (15) (previously discussed in our Repetition Duration section) reported a small significant increase (2.8 %) in muscle cross-sectional area in a group who trained with 35 % 1 RM compared with no significant gain in muscular hypertrophy for a group that used 90 % 1 RM. The results reported by Moss et al. (15), which showed that a lighter resistance was more effective than a heavier resistance, are contrary to the claim in the Position Stand.

Shinohara et al. (168) instructed five previously untrained males (~23 years) to perform isometric knee-extensor muscle actions for three minutes (2s contraction, 3s relaxation) at 40 % maximal voluntary contraction 3x/wk for four weeks. One limb was subjected to 250 mmHg tourniquet pressure to induce ischemia, while the contra-lateral limb was not restricted. There was a significant increase in maximal voluntary contraction (~26 %) and maximal rate of torque development (~60 %) in the limb subjected to the ischemia, and no significant increase in the unrestricted limb. Shinohara et al. (168) did not report any measurement of muscle hypertrophy. Therefore, this study does not support the claim in the Position Stand.

Smith and Rutherford (169) instructed 10 previously untrained males and females (~20 years) to perform four sets of 10 repetitions of concentric-only leg-press exercise with one limb and eccentric-only muscle actions with the contra-lateral limb (3 seconds each) 3x/wk for 20 weeks. Subjects performed the concentric muscle action with the foot placed on the lower portion of the footplate and the contra-lateral eccentric muscle action with the foot placed on the upper part of the plate. The authors noted that the foot placement resulted in a 35 % greater resistance for the eccentric limb. Isometric strength gains were significantly greater in the concentrically trained limb (43.7 %) compared with the contra-lateral limb (22.9 %). Dynamic (isokinetic) strength significantly increased in two out of eight test velocities in the concentric limb and five out of eight in the eccentric limb, with no significant difference between limbs. There was a significant increase in proximal quadriceps muscle cross-sectional area in the concentric (4.6 %) and eccentric limbs (4.0 %), with no significant difference between limbs. Smith and Rutherford (169) stated that their results suggest that it is not muscle force per se that is the stimulus for increasing muscular strength and hypertrophy. That is, the 35 % greater resistance in the eccentrically trained limb did not produce greater muscular hypertrophy. Therefore, their results do not support the claim in the Position Stand.

In summary, out of the three resistance-training studies (15, 168-169) cited in the Position Stand to support the use of heavier resistance and a greater training volume for muscular hypertrophy, one study (168) did not measure muscle hypertrophy, one study (169) showed no difference in hypertrophic gains with greater resistance, and one study (15), which contradicts the claim in the Position Stand, showed a significantly greater gain in muscular hypertrophy with a lighter resistance. Therefore, the claim in the Position Stand that heavy loads and high-volume resistance training are required for maximal muscular hypertrophy is unsubstantiated (Table 11).

Table 11. Summary of Muscular Hypertrophy Research.

Reference	Rating
McCall et al. (165)	↓
Moss et al. (15)	↓
Shinohara et al. (168)	↓
Smith & Rutherford (169)	↓

↑ Studies cited in the Position Stand that actually support the primary claim or recommendation.

? Studies cited in the Position Stand that support the primary claim or recommendation but contain serious flaws in the methodology or data.

↓ Studies cited in the Position Stand that fail to support the primary claim or recommendation.

* Studies not cited in the Position Stand that repudiate the primary claim or recommendation.

CONCLUSIONS

The ACSM has taken a definitive stand on resistance training. Therefore, the entire burden of proof is on the ACSM and the authors of the Position Stand to support their recommendations with peer-reviewed resistance-training studies that were available throughout the preparation of the Position Stand. They failed to meet that responsibility. Many of the recommendations are without any scientific foundation. The Position Stand fails to meet the standards for a scientifically based, methodologically sound, consensus statement.

We document numerous examples that specifically demonstrate how the authors of the Position Stand selectively reported the results of resistance-training studies. That is, they cite a couple of references that support their opinion and neglect to cite the studies that do not support it. Or, they use one or two results of a study that support their point of view and neglect to report other results from that study that do not support their opinion—a disservice to dedicated researchers at best. A number of their references have absolutely no relevance to their claims.

Readers are encouraged to scrutinize all the original resistance-training studies cited in the Position Stand. That is, carefully read the entire study, look for flaws in the methodology, decide whether the results actually support a particular hypothesis, and try to recognize when the discussion or practical application section conflicts with the reported data.

Assuming that the goals of healthy, advanced trainees are realistically within their genetic potential, there is very little evidence to suggest that intermediate or advanced trainees need to spend several hours a day performing resistance training or obsessively manipulating the training variables to attain specific goals such as muscular hypertrophy. If the goal is not within their genetic capability, no amount of resistance training will produce the desired results. For example, Van Etten et al. (170) recruited 21 previously untrained males (~36 years) and based on their initial body build expressed as a fat-free mass index (fat-free mass$\cdot$height^{-2}), classified them as a *solid* group or a contrasting *slender* group. All the subjects performed 1-3 sets of 10-15 repetitions for each of 14 exercises 2x/wk for 12 weeks. Absolute strength (~13 %) as well as strength relative to fat-free mass (~13 %) significantly increased at all angular velocities and movements tested, with no significant difference between groups for any of these changes. Both groups showed comparable decreases in fat mass (11.3 and 10.5 %, solid and slender groups, respectively). The entire group of trainees showed a significant increase in fat-free mass (1.0 kg). However, when analyzed separately the solid group significantly increased fat-free mass (1.6 kg), while the slender group did not change significantly (0.3 kg). The difference between groups was significant. The solid group also showed a significantly greater increase in body build (0.75 kg$\cdot$m^{-2}) compared with the slender group (0.26 kg$\cdot$m^{-2}). Van Etten et al. (170) concluded that the potential to increase free-fat mass, as well as the difference between groups in initial fat-free mass, are genetically determined. Unfortunately, genetic limitations of muscular strength, hypertrophy, power, and endurance are never addressed in the Position Stand.

Table 1 (p. 374) in the Position Stand, which is entitled: Summary of Resistance Training Recommendations: An Overview of Different Program Variables Needed for Progression with Different Fitness Levels (http://www.acsm-msse.org/pt/pt-core/template-journal/msse/media/0202.pdf), presents an outline of the ACSM's highly complex recommendations. The training protocols include the types of exercise (single and multiple joint), order of exercise, a specific percent of the 1 RM, repetition duration, range of repetitions, number of sets for each exercise, rest time between sets and exercises, frequency of training, and so-called periodization programs. The ACSM claims that the training protocols should vary for novice, intermediate and advanced trainees, and are dependent on specific goals such as enhanced muscular strength, hypertrophy, power, and endurance. If obsessive manipulation of these training variables really had a significant effect on specific outcomes, it would be evident in the preponderance of resistance-training studies. However, as we have specifically documented in each of the previous sections, there is very little scientific evidence to suggest that any particular program described in Table 1 (p. 374) of the Position Stand will elicit a specific adaptation such as increased muscular strength, hypertrophy, power, or endurance (Table 12).

Table 12. Summary of Resistance Training Research.

8	Studies cited in the Position Stand actually support the primary claim or recommendation.
16	Studies cited in the Position Stand support the primary claim or recommendation but contain serious flaws in the methodology or data.
59	Studies cited in the Position Stand fail to support the primary claim or recommendation.
56	Studies not cited in the Position Stand repudiate the primary claim or recommendation.

Because most advanced trainees would like to improve year round in all of the aforementioned variables (muscular strength, hypertrophy, power, and endurance), following the ACSM's recommendations is not only a daunting task for most healthy adults, but also a deterrent for compliance even in the most dedicated trainees or for elite athletes who devote a great amount of time training for their specific sport. Many people would be forced to relinquish almost every other form of physical activity in order to achieve—according to the Position Stand—a hypothetical 10 % improvement. It appears that the intention of this Position Stand is to recommend what is required for trainees to determine how much exercise they can tolerate, rather than guiding people to establish the amount of exercise required to stimulate the desired adaptations that will improve health and enhance muscular strength, hypertrophy, power, and endurance.

The Position Stand claims that a general program of resistance training used by a novice will not have the same effect in an advanced trainee, but the majority of the references cited did not involve advanced trainees.

Although there are eight studies (10, 33-34, 36, 38, 95, 121, 151) out of 139 citations in our summary Table 12 that actually support the primary claim or recommendation in the Position Stand (a mere 5.8 %), three of those studies used subjects who had undisclosed recreational experience with resistance training (36), basic experience (either 3-6 months or minimal of 6 months) in resistance training (38), or were enrolled (time not reported) in a college weight-training class (151). The other five studies involved previously untrained subjects (10, 33-34, 95, 121). Consequently, none of the eight studies (10, 33-34, 36, 38, 95, 121, 151) that support the primary recommendation in the Position Stand actually involved advanced trainees.

This ACSM Position Stand was published with so little supporting scientific evidence because the entire peer-review system failed. That is, the ACSM's Writing Group for the Position Stand failed to support their opinions with sufficient evidence; the reviewers of the Position Stand, presumably with expertise in resistance training and exercise physiology, failed to challenge a single reference; the ACSM Pronouncements Committee, Board of Trustees, and Administrative Council failed to monitor the review process effectively; and the Editor-in-Chief of *Medicine and Science in Sports and Exercise* chose to publish a document that is bereft of scientific evidence to support the claims and recommendations. Thus, it is our opinion that the problems within the ACSM are far more egregious than a highly flawed Position Stand.

RECOMMENDATIONS

What is really known about the science of resistance training is contrary to the opinions expressed in the Position Stand. That is, the preponderance of research strongly suggests that gains in muscular strength, hypertrophy, power, and endurance are the result of the following simple guidelines:

- **Select a mode of exercise that feels comfortable throughout the range of motion**. *There is very little evidence to support the superiority of free weights or machines for increasing muscular strength, hypertrophy, power, or endurance.*
- **Choose a repetition duration that will ensure the maintenance of consistent form throughout the set**. *One study showed a greater strength benefit from a shorter duration (2s/4s) and one study showed better strength gains as a result of a longer duration (10s/4s), but no study using conventional exercise equipment reports any significant difference in muscular hypertrophy, power, or endurance as a result of manipulating repetition duration.*
- **Choose a range of repetitions between three and 15** (e.g., 3-5, 6-8, 8-10, etc.). *There is very little evidence to suggest that a specific range of repetitions (e.g., 3-5 versus 8-10) or time-under-load (e.g., 30s versus 90s) significantly impacts the increase in muscular strength, hypertrophy, power, or endurance.*
- **Perform one set of each exercise**. *The preponderance of resistance-training studies shows no difference in the gains in muscular strength, hypertrophy, power, or endurance as a result of performing a greater number of sets.*
- **After performing a combination of concentric and eccentric muscle actions, terminate each exercise at the point where the concentric phase of the exercise is becoming difficult, if not impossible, while maintaining good form**. *There is very little evidence to suggest that going beyond this level of intensity (e.g., supramaximal or accentuated eccentric muscle actions) will further enhance muscular strength, hypertrophy, power, or endurance.*
- **Allow enough time between exercises to perform the next exercise in proper form**. *There is very little evidence to suggest that different rest periods between sets or exercises will significantly affect the gains in muscular strength, hypertrophy, power, or endurance.*
- **Depending on individual recovery and response, choose a frequency of 2-3 times/week to stimulate each targeted muscle group. One session a week has been shown to be just as effective as 2-3 times/week for some muscle groups**. *There is very little evidence to suggest that training a muscle more than 2-3 times/week or that split routines will produce greater gains in muscular strength, hypertrophy, power, or endurance.*

In reality, progression in resistance training is simply adding enough resistance, which is a *consequence* of getting stronger—not a requisite—to stay within the desired range of repetitions and maintain a specific degree of effort. This is achieved while maintaining the precise exercise form for each aspect of the chosen protocol. Complex manipulation of any or all of the previously discussed resistance-training variables in an attempt to enhance gains in muscular strength, hypertrophy, power, or endurance in novice, intermediate or advanced trainees is primarily based on unsubstantiated opinions, and lacks sufficient scientific evidence - empirical or theoretical - for support.

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