The Relationship of Muscular Mass to Strength

Arthur Jones

Increasing the size of a muscle will increase its strength… and the increase in strength will be in proportion to the increase in size. But it does not follow that a particular individual with larger muscles can always demonstrate more strength than another individual with smaller individual.

The ability to demonstrate strength, to produce movement against a give level of resistance, is determined by a number of factors… the size of a muscle, and thus the strength of a muscle itself (since size and strength are related) is only one factor. In later chapters we will cover the other factors involved in usable strength… but in this chapter, we are concerned only with muscular size.

Increasing the strength of a muscle by increasing its size is probably the most common goal in exercise… primarily, I think, because it is a goal that can be seen, measured, experienced. And, secondarily, because it is a goal that can be reached quickly. Millions of people have devoted large parts of their lives to this goal, and thousands of books have been written on the subject… yet the subject has remained clouded by confusion.

The facts are simple enough, and are available… but separating the facts from the myths is not always simple. One such myth concerns the subject of this chapter… the relationship of muscular mass to strength.

Most of the confusion that forms the basis of the myths related to exercise results from the multiplicity of factors involved in producing, transmitting, and using muscular strength… a muscle produces strength, but it cannot transmit or use strength without the aid of other parts of the body.

In an automobile, the engine produces power… and an engine is certainly required for the production of power, but it is not of any practical use by itself. The power produced by the engine must be transmitted by the transmission and differential, and must be used by the wheels. A larger engine will produce more power, and if the other components of the power train are capable of withstanding the forces involved by an increase in power, then the increase in the size of the engine will produce an increase in the usable power of the automobile.

In the body, the muscles perform the functions of a number of small engines, producing pulling forces in almost every direction… when the size of the muscles is increased, it becomes possible to produce more force, and if that force is properly transmitted the result will be an increase in usable strength.

So increasing the size of an engine or a muscle will increase available power… but an increase in size is not the only way to increase power. The power of an engine can also be increased by running it faster… and a somewhat similar result can be produced in a muscle. A muscle might be thought of as an engine with thousands of cylinders… but with only a rather small percentage of the cylinders attached to the electrical system at any one time. So only a few of the cylinders are available for the production of power at any given moment.

The production of power inside the cylinder of an engine is stimulated by an electrical spark… and the contraction of a muscular fiber that produces power in the form of pulling force is stimulated by an electrical impulse from the brain.

The speed, and thus the power, of an engine is limited by its ability to intake a proper fuel/air mixture… and a muscle is limited in much the same way. If an electrical impulse from the brain reaches a particular muscle fiber that has exhausted its momentary supply of fuel and oxygen, then that fiber cannot contract. And since it is impossible for a muscle to instantly replace a depleted supply of fuel and oxygen, the resulting involvement of muscular fibers is on an alternating basis… some fibers are working while other fibers are resting, replacing their stores of fuel and oxygen.

All of the fibers of a muscle are never working at any given instant… not even when the entire muscle is fresh.

If the pace of work is slow enough to permit the resulting fibers to replenish their stores of fuel and oxygen before the working fibers become exhausted, then such work can be continued for hours… such work is called aerobic work, and it will do very little or nothing in the way of increasing the size or strength of the working muscles.

But if the pace of work is increased to the point that the working fibers become exhausted before the resting fibers have fully recuperated, then a point of muscular failure will eventually result… the faster the pace of work, the faster a point of failure will be reached. This type (or pace) of work is called anaerobic work… and this is the type of work required for increasing the size and strength of muscles.

A widespread misunderstanding of the implications of the above point has resulted in very poor training practices; increasing the pace of work does not require moving the resistance faster… on the contrary, exercises involving fast movement of the resistance will do very little in the way of increasing strength.

There is a very definite limit to the possible speed of muscular contraction… and if the speed of movement of the resistance is too fast, it literally outstrips the ability of the muscle to keep up; the result being that a large part of the muscle is not involved in the work at all. If a muscle is suddenly contracted while being exposed to a low level of resistance, very rapid movement of the resistance will occur… but only a small part of the muscle will be involved in the work; movement will occur so fast that most of the muscle will never quite catch up, the movement will be completed before the muscle has time to contract.

So instead of trying to increase the pace of work by increasing the speed of movement, the resistance should be increased… and if the resistance is heavy enough, sudden movement becomes literally impossible.

Sudden movement can also be produced in another manner, by throwing weight… and this can be done in some cases where it would be impossible to move the resistance by contraction of the muscles that are trying to exercise. Again… such exercise will do little or nothing in the way of increasing strength, the actual ability of a muscle to produce a pulling force.

But, by involving a large number of other muscles in the movement, you probably will develop a style of performance that will enable you to 'lift more weight' in a particular fashion… and you may thus convince yourself that your strength has increased accordingly; when, in fact, your strength has probably remained unchanged.

For the purpose of increasing muscular size and strength, movement should never be faster than the maximum possible speed of muscular contraction… FULL LENGTH muscular contraction; and in practice, this means that the actual speed of movement should be quite slow. If you are capable of moving faster, then use more resistance… but do not increase the resistance to the point that it becomes necessary to throw the weight by involving other muscles.

A natural desire to show progress by increasing the resistance leads many trainees into very poor training habits… and then true progress comes to a halt, or is produced very slowly. The resistance should be increased, and it should be increased rapidly as possible… but it should not be increased by a sacrifice in the style of performance. A very strict style of performance is probably the single most important factor in exercise… and it certainly is an absolute prerequisite for the production of good results from exercise. Yet, in practice, the style of performance of most trainees varies from poor to pitiful.

The resistance must be applied to the muscles that you are trying to work, and it must be applied to the entire length of the muscles you are training… but this is impossible if the movement is too fast, and also impossible if all or most of the work is actually performed by other muscles.

Most people have seen examples of men who can lift a very heavy weight while showing little in the way of unusual muscular size… and other examples of men who can not lift as much weight as you would expect from their muscular size. Such examples have caused numerous people to assume that muscular size has very little to do with strength… but that impression is the exact opposite of the truth.

A short man may lift more weight than you would expect because he does not have to move it so far… and the distance of movement is just as important as the actual amount of weight involved.

A very lean (muscular) man may lift more weight than a much larger man, but if all of the other factors are the same in both cases then this is merely an indication that the smaller man actually has more muscular mass… and that the larger man's size is composed of a higher percentage of fatty tissue, which cannot contract, cannot produce force. Or a particular individual may have developed a style of performance that permits him to move a heavy weight by throwing it… and thus he may appear to be stronger than another larger man who is actually stronger.

In practice, it is almost impossible to fairly compare the strength of one man to that of another man… you can compare performances, but performance is not always a test of strength. Primarily because strength is only one of several factors involved in any type of performance.

In some ways the strength of a muscle can be compared to that of a rope… even though a rope cannot produce force by contraction. A rope can withstand a pulling force in proportion to its cross-sectional area… and a muscle can produce a pulling force in proportion to its cross-sectional area.

And since the length of a muscle is not changed by an increase in the volume of a muscle, it obviously follows that the cross-sectional area of a muscle is in direct proportion to the mass of a muscle… in proportion to the weight of a muscle, the 'size' of a muscle. Thus the size of a muscle is a direct indication of the strength of the same muscle.

When you increase a particular man's muscular size you will increase his strength… he will be stronger as a direct result of the increase in muscular size, and he will be stronger in proportion to the increase in muscular size. But he still may not be as strong as some other man with much smaller muscles… because the smaller muscles of the other man may be working with advantages not available to the larger man; better bodily leverage… or greater neurological efficiency… or some other factor that gives his muscles an edge that more than compensates for their smaller size and actually lower level of strength.

In effect, any man will be stronger than he was if you increase the size of his muscles… but no one factor will ever make him equal to all other men.

Many of the other factors that contribute to demonstrations of strength cannot be changed… but you can increase the muscular size of almost anybody; and doing so will make any individual stronger than he was. So the mass of a man's muscles is important for two reasons… because it is directly related to his strength… and because it is the factor most subject to change, the easiest factor to improve.

Having increased a particular individual's muscular size as much as possible, he may still not be able to demonstrate as much strength as another man with less muscular mass… but he certainly will be able to demonstrate far more strength than he, as an individual, was capable of doing before he increased his muscular size.

A large part of the confusion on the subject of the relationship between muscular size and strength undoubtedly results from current standards for physique competition… and at least part of this confusion also results from the fact that competitive weightlifters seldom if ever have a bodybuilder type of physique.

A few bodybuilders are very strong… but few bodybuilders can demonstrate a level of strength in proportion to their muscular size… and some bodybuilders are actually quite weak when due consideration is given to their muscular mass. But this weakness has absolutely nothing to do with the 'quality' of their muscular mass… their muscles, like those of anybody else, are strong in proportion to their size; but poor bodily leverage or some other factor makes it impossible for them to transmit a very high proportion of their muscular strength to their limbs… in effect, they have a powerful engine but a poor transmission. They can produce the power, but they can't use much of it.

Wide shoulders, narrow waist and hips, long legs, short torso… given those bodily proportions and a greater than average muscular mass, and a man may become Mr. America. He may look strong, but in fact his strength literally cannot be in proportion to his appearance of strength. With those bodily proportions a man's muscles are forced to work at a given disadvantage.

In contrast, a competitive weightlifter may not appear to have much more than an average amount of muscular mass… yet be able to demonstrate great strength. But he almost certainly will have rather narrow shoulders, a thick waist and wide hips, short legs and a long torso… those are the bodily proportions require for building greater strength; but a man with those proportions will seldom have a pleasing physique by present standards.

Over a period of the last thirty years, bodybuilders and weightlifters have gradually drifted apart, although they continue to use the same tool (the barbell) and usually perform much the same exercises. Such a separation into two distinct groups is merely a result of natural selection… men with potential to build a Mr. America physique by present standards simply do not have the potential to demonstrate great strength… and men with the potential to build great strength cannot produce the type of physique required for a Mr. America contest.

Usually within a fairly short period after starting to train, an individual will almost be forced in one direction or the other. If his strength increases rapidly with little increase in his muscular mass, then he will be encouraged to turn his interests in the direction of competitive weightlifting… but if his muscular mass increases out of proportion to his strength, then he will probably become a bodybuilder.

Draft horses are built for power, race horses are built for speed… and men fall into very similar categories. You can increase the muscular mass of a draft horse, and doing so will make him both stronger and faster, but it will never make him as fast as a good race horse. And you can increase the muscular mass of a race horse, and again it will make him both stronger and faster, but he will never be as strong as a good draft horse.

But the important point to be understood is the simple fact that both types of horses will be BOTH STRONGER AND FASTER if you increase their muscular mass. And the same thing applies to a man. You cannot change a man's physical type… but you can do a lot for him regardless of his type.

The muscles are the engines of the body… producing both power and speed. A larger engine will never make a race car out of a truck, but it will make the truck more powerful and faster.

AND REMEMBER… the size, and thus the strength, of the muscles is one important factor that you can do something about.

Another widespread myth concerns the relationship of muscular strength to muscular endurance… WHEN, IN FACT, THE TWO FACTORS ARE ONE AND THE SAME THING. Having accurately measured a man's strength, you have also measured his muscular endurance, and vice versa.

In general, a man can perform one repetition with an amount of weight that is 20% heavier than he can handle for ten repetitions. If he can perform ten repetitions of the bench-press with 250 pounds, then he can handle 300 pounds for one repetition.

Some variation in this percentage will occur on an individual basis, but every many will have a certain, fixed relationship between his strength and muscular endurance. One man might be able to handle only 17% as much more weight for one repetition as he can for ten repetitions… and another man might handle 22% more… but the relationship will remain constant in all cases.

When exercises involving a very high number of repetitions are performed, then the relationship of strength to muscular endurance may not appear to hold true… but this is an illusion produced by the fact that the other factors are then involved; a point of failure may result from an unwillingness on the part of the subject to continue, perhaps because of the pain involved in high repetition exercises… or a point of failure may result from cardiovascular inability, which really has nothing to do with the strength or endurance of the muscle itself. Or a trainee may fail with a heavier weight simply because he has never lifted that much weight before and is actually afraid to try.

In practice, strength increases (and increased endurance) are usually produced most rapidly by exercises involving a fairly constant number of repetitions… for reasons that are not fully understood, best results are almost always produced when at least 6 repetitions are involved; but not more than 15 repetitions should be performed in most cases.

Personally, I prefer an even narrower range of possible repetitions… 8 to 10, although I do perform as many as 15 repetitions in a few exercises.

But in any case, the selected number of repetitions should be merely a 'guide figure'… in fact, you should perform as many repetitions as momentarily possible without sacrificing good form. Do not stop at 10 repetitions merely because that is the upper limit of your guide figures, continue for as many repetitions as possible… 12, 15, or whatever number you can perform in good form.

BUT… if you can reach or exceed your guide figure, then that is a signal to increase the resistance; the fact that you can perform more repetitions than you anticipated is proof that your muscles have grown, so you are stronger, and need more resistance.

If, on the other hand, you are unable to perform as many repetitions as are called for by the lower guide number, then you have overestimated your strength and the resistance should be reduced.

Muscular size and strength are increased by exercises that involve the overload principle of training… the body will attempt to accommodate itself to meet a higher than usual demand. A certain level of muscular size and strength is natural… building an unusual degree of strength demands the imposition of loads that the existing level of strength cannot easily handle.

When a muscle is forced to work very close to its existing level of ability, then it will respond by increasing its size and strength… but no amount of work at a low level of intensity will produce a similar result. You cannot build great muscular size and strength by performing a large amount of work… instead, you must train very briefly but very hard.

Another common myth in the field of exercise equates the 'amount of work' with the 'intensity of work'… which is, I suppose, an expectable result of the widespread habit of equating MORE with BETTER.

But in fact, you can have one or the other… NOT BOTH. High-intensity exercise is required to build size and strength… but a large amount of high-intensity work will produce losses in muscular size and strength instead of gains.

Literally millions of trainees do perform enormous amounts of work as a routine part of their regular training… and a few of them do produce apparently worthwhile gains in muscular size and strength, EVENTUALLY. But little if any of this exercise is actually high-intensity work… instead, their exercises are almost always terminated several repetitions short of an actual point of momentary muscular failure.

Such a low-intensity style of training can be tolerated by the system, almost regardless of the amount of training, and it certainly will help to maintain an existing level of size and strength… BUT IT WILL DO LITTLE OR NOTHING TO BUILD ADDITIONAL SIZE AND STRENGTH.

High-intensity training is required to build muscular size and strength… but there is a very definite limit to the amount of high-intensity training that the body can tolerate.

And in any case, since only an actually small amount of high-intensity training is required to stimulate maximum possible rates of muscular growth, why train for hours when better results can be produced by a very few minutes of proper training… and why spend years reaching a goal that can be, and should be, reached in months, or even weeks?

If a trainee insists upon performing a large amount of exercise, then he will be forced to lower the intensity of his training… and eventually, most trainees fall into a rut where their output of work exactly equals their recovery ability. Even if growth is being stimulated, and it seldom is by such

training, the body does not respond, literally cannot respond… because the recovery ability of the body is constantly being drained by the amount of training, and nothing is left over for growth.

Eating more is not the answer… because the body can process only so much food. Sleeping more is not the answer, either… because the body can tolerate only so much sleep. While training with true high-intensity you may have to eat and sleep a bit more than normal… but an excess amount of either will have a counterproductive result.

The simple answer is… train LESS, but train HARDER.

Stimulate growth by working your muscles very briefly but as hard as momentarily possible… then leave them alone for two or three days and give them a chance to recover and grow. A reasonable amount of low-intensity work added to a proper high-intensity workout probably won't do much harm, but it will do little or nothing in the way of speeding your progress… and if carried to extremes, which it frequently is, it can easily prevent growth, or even produce losses in muscular size and strength.

A maximum possible rate of growth for one man may well be a very slow rate of growth for another man… but growth should be constant in all cases. If a constant rate of growth is not being produced then there are really only three possibilities that might account for the lack of progress… (1) the individual is not training hard enough to stimulate growth… (2) an excess amount of training is being performed and growth is being prevented… or (3) the individual has reached the limit of his muscular potential.

A very high level of strength is perfectly normal and natural for a man… if his muscles are regularly exposed to a high-intensity of work… and if the amount of work is not so high that it amounts to overwork.

And a fairly rapid rate of growth is also perfectly normal and natural for a man… if the conditions are right; if the conditions are such that growth is being both stimulated and permitted.

Farmers soon learn not to plant more crops than they can harvest… because, at best, their efforts will be wasted; and anybody who has ever tried to work 18 hours a day at a physically hard job soon learned that his ability to work rapidly declined… so that, rather quickly, he found himself doing less work in 18 hours than he would normally have performed in 8 hours.

Yet, in practice, we see thousands of trainees who are regularly devoting 20 or more weekly hours to their workouts, usually training five or six days a week, for three or four hours during each workout.

NOW, IN FACT… very little of this three or four hours is actually devoted to training; most of the time is spent sitting or standing around resting between sets, or between exercises. So most of the training time is wasted… which under the circumstances, is really the best thing that can happen. BECAUSE… if a man actually tried to train nonstop for three or four hours it would probably kill him, and it certainly wouldn't make him grow.

But you can train for fifteen or twenty minutes, or a bit longer, in an almost nonstop fashion… by performing only one set of each exercise, and by arranging your exercises in such an order than one muscular group is resting while another group is working. Having been worked to a point of momentary failure, the biceps of your arms must be rested… but there is nothing to stop you from working your triceps hard while the biceps are resting. AND, IN FACT… the biceps will actually recover more quickly if the antagonistic muscles (the triceps) are worked while the biceps are resting.

Building strength is one thing… demonstrating strength is another matter entirely. But in the gym you are trying to stimulate growth, and the actual amount of weight is of very little importance if it is at least heavy enough to work the muscles to a point of momentary failure within a reasonable number of repetitions.

You probably could use more resistance, or perform more repetitions, or both… if you rested several minutes between exercises, or between sets of the same exercise. But remember, you are trying to exhaust the muscles… and if a lighter weight will produce the same result during a shorter workout, then the growth stimulation will be the same in either case.

The muscles don't know or care how much weight is involved… all they can sense is how it feels at that precise moment, and a fairly light weight will feel heavy to a momentarily tired muscle. Five minutes later the same weight might feel very light to the same, but now rested, muscle; and thus the same number of repetitions performed five minutes later with the same weight might do absolutely nothing in the say of stimulating growth.

If it feels heavy to the muscles, then the resistance is heavy enough… regardless of the actual weight.

Do not make the common error of performing your workouts in such a manner that you can handle as much weight as possible... instead, make the work as hard as possible for the muscles you are trying to stimulate. Don't look for ways to make your exercises easier, so that you can handle more weight… instead, look for ways to make every exercise as hard as you can. Performed in one way, you may be able to use 200 pounds in a particular exercise… performed in another way, the same exercise may produce far better results with only 50 pounds resistance.

Chinning (or 'pull-ups') can be performed in at least three different styles… (1) by swinging the body and using the resulting momentum to help raise the body… (2) by moving steadily, but fairly rapidly, up and down with little or no swinging… or (3) by raising and lowering the body slowly with a pause at the top and bottom.

The first, or 'swinging' fashion will produce the highest possible number of repetitions, and will do little or nothing to increase the strength of the involved muscles… the second, slower, fashion will not permit as many repetitions, but will do quite a bit to stimulate muscular growth… but the final, very slow style, is by far the best, even though you will not be able to perform many repetitions.

So if you make it a practice to try to lift as much weight as possible, or to perform as many repetitions as possible with a given resistance… it frequently happens that the style of performance suffers to the extent that the entire purpose of the workout is perverted. You should use as much resistance as possible… and you should perform as many repetitions as momentarily possible… but not if increasing the resistance or the number of repetitions results in a relaxation of style.

Good form (or 'style of performance') may not be everything… but without it, you have little or nothing of value. So it certainly is a requisite for good results from exercise… and yet it remains the most neglected factor in exercise.

The most persistent myth on the subject of muscular mass concerns the relationship between muscular size and flexibility… in spite of all of the evidence to the contrary, and with literally nothing to support such a belief, most people still firmly believe that an individual with large muscles is somehow restricted by his muscles, suffers from a limited range of movement, and is probably very slow and clumsy.

WHILE, IN FACT… careful tests of large numbers of men with unusual muscular size have clearly demonstrated that such men are almost always more flexible, and faster, than average men. Building large and strong muscular structures requires exercises with very heavy resistance, and the use of such heavy resistance is also required for increasing flexibility… the limbs must be stretched into positions far beyond a normal range of movement, and it takes heavy resistance to produce such a degree of stretching.

And while it certainly is possible to produce some increase in the size of your muscles without stretching, by the performance of limited, mid-range movements… it is also true that the development of a maximum degree of muscular size and strength is simply impossible without the use of full-range, stretching movements against heavy resistance.

Flexibility is a product of several factors… (1) the individual geometry of the joints… (2) individual bodily proportions… (3) individual percentage of fatty tissue, and the distribution of such fatty tissues… (4) condition of the connective tissue… and (5) strength of the muscles, and the relative strength of antagonistic muscular structures.

AND AGAIN… some of these factors are subject to change, can be improved; but some are not subject to change.

Little or nothing can be done to alter the geometry of the joints or bodily proportions… and nothing can be done to improve the distribution of fatty tissue, although it is possible to reduce the overall amount of fatty tissue… and, if the connective tissue has been damaged, you may or may not be able to repair the damage.

But you can do something about the muscles… quite a lot, as it happens. And doing as much as possible will almost certainly have the effect of greatly increasing your flexibility… while going a long way in the direction of reducing the chance of injury.

If a limb is forced into a position that is well outside its normal range of movement, then injury is almost certain… something must tear loose in order to permit such an unusual range of movement, and it will. But if the range of movement has been greatly increased by stretching exercises involving heavy resistance, then the same position could be reached with no chance of injury. Which is not meant to imply that any possible degree of flexibility will make injury impossible… but a high degree of flexibility certainly will reduce the chances of injury.

When we first built a Pullover machine, we incorporated a range of movement of 160 degrees of rotation around the axis of the shoulder joints, and that was enough for most subjects… but after using the machine for a while, we found that our flexibility was increasing, so we were forced to redesign the machine and increase the range of movement.

Then, over a period of less than a year, we were forced to increase the range of movement of the machine several more times… until, finally, one subject was able to demonstrate an almost unbelievable degree of flexibility in this movement, more than 270 degrees of rotation around the axis of the shoulder joints.

And in the meantime, all of our subjects had greatly increased their starting degrees of flexibility… and most subjects could demonstrate a range of movement of approximately 240 degrees in this exercise after using the machine for a few months, a 50% increase in that area of movement.

Because of individual variations in bodily geometry, some subjects would never be able to produce such a degree of flexibility… but any subject can greatly increase his existing range of possible movement by using these full-range movements against heavy resistance.

Almost all of the many books on exercise strongly urge the reader to practice full-range movements… but as it happens, such advice is largely wasted; BECAUSE… a full-range movement against resistance is literally impossible in most exercises.

A barbell curl is not a full-range exercise… because there is no resistance at the start of the movement, and no resistance during the last part of the movement. Stretching is not provided at the start of the movement, and there is no resistance in the finishing position.

A bench-press is not a full-range exercise for much the same reasons… because there is little or no stretching in the bottom position, and because the arms are ‘locked-out’ under the weight in the top position, and thus the resistance is supported by the bones, and no work is provided for the muscles in that position.

Almost all conventional exercises suffer from the same shortcomings, the same limitations… and for the same reason; because, quite literally, you are trying to perform the impossible when you attempt to provide your muscles with full-range exercise while exposing them to a straight-line source of resistance.

Muscular contraction produces a rotary form o movement of the related body-part… the muscle contracts in an approximately straight line, produces straight-line force as a source of power, but this straight-line force is converted to a rotary form of movement by the articulation of the joint. So the muscles move in straight lines, but the movement of body-parts is rotary.

For the most of the last seventy years, people have been trying to force their muscles to work within a framework of limitations imposed by an imperfect tool, the barbell, or exercise machines designed to duplicate the functions of a barbell. And you certainly can provide 'exercise' with a barbell… but you as certainly can NOT provide full-range exercise with a barbell.

Full-range exercise has certain basic requirements… and if any one of those requirements is missing, then full-range exercise is simply impossible. There are ten basic requirements for full-range exercise; most barbell exercises provide only three of these requirements… and a few barbell exercises provide four of the requirements.

Yet all of the requirements are equally important… because, without any one of them, the goal of full-range exercise is simply impossible to reach.

And why is full-range exercise so important?

BECAUSE… without full-range exercise, you are working only part of a muscle, and usually the weakest part of the muscle at that. And you cannot build a maximum level of strength throughout a muscular structure by exercising only part of the muscle… while utterly ignoring a large part of the same muscle.

A compromise of sorts can be reached by performing one exercise that provides stretching for a particular muscle… and another exercise that provides work in a position of full muscular contraction… and yet another exercise that produces work in the mid-range of possible movement. But best results are produced when exercises provides resistance in every position, from a fully stretched starting position to a finishing position of full muscular contraction… a truly full-range exercise. But, with a barbell, that is an impossible dream.

Nearly thirty years ago, the author set out to design and build a truly full-range exercise machine… but first it was necessary to determine the actual requirements for full-range exercise. Until and unless these requirements were fully understood, it was impossible to design the required tool.

AFTER THE FACT… having finally determined the actual requirements for full-range exercise, all of the factors appear obvious; yet, even now, after the requirements have been identified and are understood… such understanding is not widespread. For that reason, in the next few pages, I will attempt a very simple explanation of all the actual requirements for full-range exercise. But it should be clearly understood by the reader that most forms of exercise do not provide all of the requirements for full-range exercise… and, lacking these requirements, the promoters of such forms of exercise have gone to great lengths in their attempts to confuse the issue.

And the situation is confused, to the point that millions of people simply don't know what to believe. Yet the facts are clear… and a careful reading of the next few pages should make them obvious to almost anybody.

1-POSITIVE WORK… or 'concentric contraction.'

When you lift a weight you are performing 'positive' work. Your muscles are producing movement by concentric contraction, by reducing their length.

Almost all forms of exercise involve positive work… even if movement of the resistance is not produced. But some forms of exercise have only positive work.

Within the last two or three years, a great deal has been claimed for a form of exercise variously called 'Isokinetics' or "Isonetics' or by one or more of a number of other names. But, by any name, such a form of exercise is limited to positive work… and all such exercises are based on friction of one kind or another.

A positive-only style of training could be produced with a barbell in either one of two ways… (1) if you lifted a barbell, and then immediately dropped it upon reaching the top position of movement, and then lifted it again, and then dropped it gain, and so on, then you would be exercising in a positive-only fashion… or (2) if, with the help of assistants, you lifted the barbell, and if the helpers took it from you as soon as it reached the top position and lowered it back down for you, then you would be performing only the positive part of the work while the assistants performed the negative (or lowering) part of the work.

Such a style of training with a barbell would be very dangerous in the first instance (dropping the barbell from the top position)… and would be impractical in the second instance, because of the need for helpers… and would not be very productive in either case. Because a positive-only form of exercise is unavoidably lacking several of the important requirements for productive exercise.

Positive work is certainly of value in exercise… but 'positive only' exercise suffers from a number of limitations.

2-NEVATIVE WORK… or 'Eccentric contraction.'

When you lower a weight you are performing 'negative' work. Your muscles are LIMITING MOVEMENT by eccentric contraction, while increasing their length.

If a barbell, for example, is simply dropped from the top position, then negative work is not performed… instead, the normal downwards movement of the resistance that is produced by gravity must be limited; normal acceleration must be prevented, movement must be slowed.

A negative-style of training can be provided in several ways… (1) by the use of assistants who lift the weight for you, so that you can limit your efforts to slowly lowering the weight… (2) by climbing upon on a chair into the top position of a chinning exercise, you can limit the exercise to a negative-only style by lowering yourself down from the top position… or (3) by using a mechanical arrangement that lifts the weight so that you can lower it.

The first style is impractical due to the requirement of helpers… the second is limited to only a few exercises, chinning, dipping and a few others… and the third style requires special equipment. Thus, at this point, a negative-only style of training remains impractical for most people.

HOWEVER… it should be clearly understood that the negative part of exercise is one of the most important parts of exercise, and is probably the most important part of exercise performed for the purpose of increasing strength. So, the degree that is possible under the prevailing circumstances, the negative part of exercise should be given as much emphasis as possible.

Many people make the mistake of paying close attention to the positive part of their exercises, but then ignore the negative part… they lift the weight smoothly and in good form, but then lower it back down in a haphazard manner; thus denying themselves a large part of the potential benefit of their exercises. Instead, the weight should be lifted in a smooth, steady motion, without pause and without jerking or sudden movement… then it should be lowered in exactly the same fashion, smoothly, fairly slowly, and steadily.

AND… it must also be understood that several of the other important requirements for productive exercise are simply impossible without negative work. Stretching, for flexibility… pre-stretching, for the neurological stimulation required for a high intensity of muscular contraction… and resistance in the position of full muscular contraction at its end of an exercise movement are literally impossible without negative work.

Negative work is possible only when there is a source of back pressure… a force puling in a direction opposite to the direction of movement produced by muscular contraction. During barbell exercises, your muscles are pulling ‘up’… and the force of gravity is pulling ‘down.’ So a barbell provides both positive and negative work.

But the friction-based types of exercise… Isokinetics, Isonetics, or whatever… do not provide negative work. Because there is no back pressure of force trying to pull your muscles back into the starting position. In such exercises, resistance is provided only while you are moving in a positive direction… and if you stop moving, the resistance instantly ceases.

Lacking the required back pressure for negative work, such exercises also fail to provide several other requirements for productive exercise… requirements that are related to and dependant upon negative work. Prior to the start of movement, there is no back pressure of force to pull the joints into a stretched position, and no force to ‘pre-stretch’ the muscles before the start of contraction… thus such a form of exercise does absolutely nothing for flexibility (which requires stretching), and also does not provide a high intensity of muscular contraction (which requires pre-stretching).

3-ROTARY-FORM MOVEMENT

Muscular contraction occurs in an approximately straight line… 'straight line' force is produced. But the related body-part that is moved by muscular contraction does not move in a straight line… instead, the body-part rotates, as it must, since it is working around the axis of a joint.

So the articulation of the joint converts the straight-line force of muscular contraction into the rotary-form force required for movement. Much the same thing occurs in an engine when the crankshaft converts the straight-line power produced by the cylinders into the rotary-form power required by the wheels.

Most forms of exercise provide resistance in only one direction… 'down' as a result of the force of gravity during barbell exercises… or 'up' or 'across' during Universal machine exercises where the resistance is redirected by the use of pulleys or levers… or in any possible direction, BUT IN ONLY ONE DIRECTION, during Isokinetic type exercises… but in all three cases, one factor remains constant: resistance is provided in ONLY ONE DIRECTION, a straight-line direction.

Obviously, then, a full-range exercise becomes literally impossible… since the involved body-part is constantly changing its direction of movement, is rotating around the axis of its joint. In such cases, resistance can be provided at the start of an exercise movement… OR during the mid-range of movement… OR at the end of a movement, but it CAN NOT be provided throughout a movement.

Resistance is provided only when the direction of movement is opposed to the direction of pull of the resistance… and that is impossible when you are trying to apply a straight-line source of resistance against a full range of rotary-form movement. During a barbell curl, for example, there is no resistance at all at the start of the movement; because the resistance is pulling 'down' while the movement is 'forward'… the result being that the resistance is 90 degrees 'out of phase' with the direction of movement.

Then, shortly after the curling movement is started, the direction of movement changes to the point that the resistance is more than 90 degrees out of phase with the direction of movement… at which point, some resistance is provided. But not much, because you are still pushing the weight more than you are lifting it.

You are actually lifting the weight only during one small area of movement… at the point where your hands are going straight up, while the resistance is pulling straight down. The so-called 'sticking point' of the curl… where the weight feels far heavier than it does during any other part of a curl. Of course the barbell is no heavier at that point than it is at any other point throughout the movement, but its direction of pull is exactly 180 degrees out-of-phase with your direction of movement so it feels heavier… and, to your muscles, it is heavier.

But if you get past that point, then the pull of the resistance rapidly drops off… and near the end of the movement, it drops off to literally zero.

Thus the weight seems to change during a curl, from zero to very heavy and then back down to zero again… all of which apparent changes are a result of the fact that you are providing a rotary movement with a straight-line source of resistance. The biceps muscles, the muscles that you are trying to work during a curl, are provided with heavy exercise only during a very limited part of the movement… and during the rest of the movement the resistance is far too light.

For full-range exercise the body-part that is being moved by muscular contraction must be rotating on a common axis with the source of resistance… in effect, the joint (the elbow joint in the case of a curl) must be in line with the axis of a rotary form of resistance. When this arrangement of axis points is correct, then the resistance is always exactly 180 degrees out-of-phase with your momentary direction of movement. You are always 'lifting' the weight regardless of your actual direction of movement.

Without such rotary-form resistance, full-range exercise is simply and utterly impossible.

4-STRETCHING

A relaxed arm does not hang in a fully straightened position… it tends to remain slightly bent. Bent to the degree that is required to equalize the pull of the antagonistic muscles of the upper arm, the biceps that bend the arm and the triceps that straighten the arm… which muscles are never totally relaxed, are always pulling slightly in opposite directions.

You can straighten the arm by contracting the triceps while attempting to relax the biceps as much as possible… but you cannot stretch the biceps without an external source of force. Force external to the arm itself.

And if such stretching is not a regular part of your exercises, you will gradually reduce your degree of flexibility… you will lose the ability to move into positions that were previously possible. And your chances of injury will be greatly increased… because, if you are forced into a position that is far beyond your momentary possible range-of-movement, something will be torn loose in order to permit the movement. The muscle itself may be torn loose from its attachments, or your tendons may be damaged.

Young children are normally very flexible, and then as they grow older they lose a great deal of that flexibility. Part of which loss is apparently unavoidable… because some of a child's flexibility results from the fact that his bones are very flexible, and some of it results from the fact that his limbs are usually fairly thin. Both of which factors will unavoidably change with age.

But a certain part of the loss in flexibility that usually occurs between childhood and maturity is simply a result of inactivity… a lack of stretching. And at least some of the many thousands of athletic injuries that occur every year are results of an 'unnatural' loss of normal flexibility.

A low level of strength can be maintained with absolutely nothing in the way of systematic exercise… and an apparently normal range-of-movement can also be maintained without exercise. But in fact, losses in both strength and flexibility will steadily occur without exercise… until, one day, you may suddenly find yourself far weaker and far less flexible than you even suspected. At which point, if you need strength and flexibility, it is a bit too late.

Some barbell exercises do quite a bit for flexibility, and some do not… depending upon the degree of stretching that is involved. Exercises performed on a Universal machine generally provide less stretching than similar barbell exercises, primarily because the resistance is supported in the starting position. Isokinetic type exercises do absolutely nothing for flexibility, because there is no stretching at all.

5-PRE-STRETCHING

Stretching is primarily related to the joints and the connective tissue… but 'pre-stretching' is related to the muscle itself.

When a muscle is contracted from a relaxed starting position, the resulting contraction is not as strong as it could be. Pre-stretching is required for a high-intensity of muscular contraction.

All of the fibers in a muscle do not contract at the same time, regardless of the amount of resistance… a muscle will fail under a load that it could move if all of the fibers were involved at the same time, and it will fail with most of the fibers still relaxed.

But if a muscle is pre-stretched prior to contraction, then it will involve a higher percentage of its fibers in the following contraction. The act of pre-stretching a muscle sends a signal to the brain that results in a higher than normal intensity of contraction… a center in the brain is warned in advance that the load is heavy and that as many as possible of the available fibers will be needed.

Barbell and Universal machine exercises provide this essential pre-stretching in proportion to the amount of stretching involved… so some barbell and some Universal machine exercises provide pre-stretching, and some do not. Isokinetic exercises, of course, do not provide pre-stretching… which is impossible without the back pressure of negative-work potential.

6-AUTOMATICALLY-VARIABLE RESISTANCE

Muscles are not equally strong in all positions… and movement produces large-scale chances in the mechanical efficiency of the involved joints; as a result of these two factors, you are much stronger in some positions than you are in other positions.

Thus, if the resistance remains constant in all positions, it will be correct in only one position… and too light in all other positions throughout a full range of possible movement.

You will be unavoidably limited by the amount of resistance that you can handle in your weakest position… because, if you try to use more resistance, then it will be impossible to move it through the weakest area of movement.

In practice, some variation in available resistance occurs in almost all exercises, even though the actual weight of the resistance remains constant… for example, in a barbell curl there is no available resistance in either the starting or finishing position of the exercise, and there is a constant change in the level of available resistance throughout the movement as a result of the changing 'lever arm' (or moment arm) of the resistance. But such variations in resistance are random in nature and have no relationship to the ability of the muscles to handle resistance in any particular position.

If a rotary-form curling machine is built with a round pulley directly in line with the elbow joints, then the resistance will be exactly the same in all positions throughout a full range of possible movement… but it won't 'feel' the same during the movement. Instead, it will feel very heavy at the start of the movement… then, as movement occurs, it will appear that the weight is getting lighter, but only because you are moving into a stronger position… and, later in the movement, it will seem that the weight is almost ridiculously light, because you are then in your strongest position… and, finally, at the end of the movement, the weight will seem to get heavier again, because your level of available strength is reduced in that position.

The resistance in a barbell curl starts out literally zero… then increases rapidly to a peak after 90 degrees of movement… and then drops off to zero again near the end of the curl; so a barbell curl has a pattern of available resistance that might appear correct at first glance… 'up to a peak and then back down again.' But in fact the resistance in a barbell curl starts out far too low, increases far too rapidly, and then drops off again too rapidly.

But changing from a barbell curl to a rotary-form curling machine does not entirely solve the problem… because the level of resistance in the various positions throughout the movement is still not in accord with the available strength in the same positions.

In a barbell curl, the available resistance changes, but it changes too fast and too much… in a rotary-form curling machine, the resistance does not change at all, and it should.

This problem was solved by the invention of the Nautilus 'cam'… instead of building our machine with a round pulley, we used an eccentric pulley, so that the available resistance changes instantly and automatically as movement occurs.

At the start of a curl in a Nautilus curling machine, the radius of the pulley is fairly small… in that position, you are not able to produce as much force as you will be able to later in the movement, so the machine gives you a mechanical advantage in that position… then, as you move into a stronger position, the radius of the pulley gets larger, thus providing more resistance. Throughout the full range of possible movement the radius of the pulley changes, becomes larger or smaller as it must to accommodate the level of strength available in any and all positions.

7-BALANCED RESISTANCE

Having provided automatically-variable resistance, the resistance must then be varied in accord with your available strength in all positions… in effect, it must be 'balanced' in relation to your strength in various positions.

Variation in resistance is not enough by itself… as mentioned earlier, even barbells provide variation in resistance, but it is random variation with no relationship to the variations that occur in your available strength during an exercise.

So the exact shape of the cam (or eccentric pulley) is very important… it must provide as much resistance in every position as you can handle in that position, but no more. While a couple of small companies are not hesitantly, and illegally, trying to copy the Nautilus cams… they are doing so with no real understanding of just what shape is actually required. Having a cam is not enough… it must be the right cam for the particular application. Ford automobiles have cams, and Chevrolets have cams… but put a cam from a Ford in a Chevrolet and see what happens. If it works at all it will work incorrectly… and it will probably ruin the engine in short order.

So a cam, a correctly designed cam, is required to balance the resistance in relation to your available strength.

8-DIRECT RESISTANCE

Muscular contraction produces 'direct' movement of the body-part to which the muscle is attached.. for example, during a curl, the contraction of the biceps results in movement of the forearm, and the biceps is attached to the forearm.

The hand, since it is attached to the forearm, is also moved… but it is not directly moved; instead, the hand is 'indirectly' moved.

For direct application of resistance, the resistance must be applied to the actual body-part that is attached to and directly moved by contraction of the muscle you are trying to work… in a curl, for example, this means the resistance would have to be applied against the forearm instead of the hand.

In a curl, as it happens, such direct application of resistance is of little or no importance… because the relative strength of the curling muscles is not out of proportion to the strength of the forearm muscles that are involved in keeping the hand straight in line with the forearm muscles that are involved in keeping the hand straight in line with the forearm during a curl. So, in this case, other muscles do not limit your curling ability… even though the resistance is not directly applied.

But in most exercises, the resistance must be applied directly in order to overcome the limitations of other, weaker muscles. Exercises designed for the large muscles of the torso suffer badly from indirect application of the resistance… since the muscles of the arms are also involved in these exercises, a point of failure is reached when the arm muscles become exhausted, and this occurs long before the larger, stronger muscles of the torso have been worked heavily enough for the production of good results.

Chinning-type exercises are performed primarily for the purpose of working the large muscles of the upper torso… but these exercises also involve the bending muscles of the arms. As a consequence, the relative low strength of the arm muscles results in a poor exercise for the torso muscles… because the arms become exhausted and force you to stop the exercise long before the torso muscles have properly worked.

Thus, in order to work the torso muscles correctly, the resistance must be directly applied against the 'prime body-part'… the body-part that is actually attached to and moved by the muscles of the torso. In practice, the resistance must be directly applied against the upper arms… against the elbows.

What happens to the forearms and hands during the exercise is of no slightest importance… so long, at least, as the forearms and hands do not get in the way of the movement.

In a Nautilus Pullover Torso machine, the resistance is applied directly against the elbows… as it must be. So the large muscles of the torso can be worked directly… without suffering from limitations imposed by the involvement of other, smaller and weaker, muscles.

Most barbell exercises and most barbell-like exercises performed on a Universal machine do not provide such direct resistance… and Isokinetic exercises in general suffer from the same limitation. There are a few exceptions… for all practical purposes, a curl is a direct exercise regardless of how it is performed… and a wrist curl is a direct exercise… and so are leg extensions and leg curls. But in general, direct exercise is provides only by Nautilus equipment.

9-RESISTANCE IN THE POSITION OF FULL MUSCULAR CONTRACTION

Full muscular contraction unavoidably occurs only in a position where additional movement is impossible… so it should thus be obvious that an Ioskinetic form of exercise provides no work at all in the finishing position of an exercise. Because Isokinetic exercises provide resistance from friction, and friction is produced by movement… thus, when movement stops, friction stops, and without friction there is no resistance, and without resistance there is no exercise.

There is no 'back pressure' of negative-work potential pulling against your muscles… and thus no exercise in the finishing position of full muscular contraction.

Most barbell exercises and most Universal machine exercises also provide no work in the finishing position… but for another reason; because the body-parts are 'locked out' under the resistance and the weight is supported entirely by the bones.

But lock-outs occur during all major barbell exercises and all major Universal machine exercises… during curls, all forms of pressing, squats, leg presses and many other exercises. Because, in these exercises, there is no effective resistance at the end of the movement… the lever arm (or moment arm) of the resistance is reduced to zero, and no resistance is being applied to the muscles.

Again, there are exceptions… a few minor barbell exercises and Universal machine exercises do provide resistance in the finishing position; a few such exceptions are wrist curls, calf raises, sit-ups, leg raises, and shoulder shrugs.

10-UNLIMITED SPEED OF MOVEMENT

Isokinetic exercises are based on friction… which results in 'limited the speed of movement.' This can be done in a number of ways, by the use of an inertia-reel or by the use of a hydraulic cylinder, or in several other ways… but the result is much the same regardless of how it is accomplished.

The speed-of-movement in barbell exercises and in Universal machine exercises is not limited… so these exercises do not suffer from this limitation. And, of course, the speed-of-movement is not limited in Nautilus exercises.

The actual speed-of-movement during a properly performed exercise should vary during the exercise… during the first few repetitions the speed should be fairly slow and constant, without jerking… then, during later repetitions, as the muscles become tired, the speed should be even slower, and jerking should still be avoided… and, finally, as the muscles reach a point of momentary exhaustion, the speed of movement should be very near zero.

So the speed-of-movement should not be limited… but since this is the basis of Isokinetic forms of exercise, the principal upon which they rely in order to function at all, these exercises are unavoidably limited in this fashion, and they suffer badly as a result.

At the start of a movement using an Isokinetic form of exercise, there is no resistance at all until your speed-of-movement reaches the pre-set speed-of-movement of the machine… so there obviously is no resistance (and thus no exercise) at the start of an Isokinetic movement.

Then, at the end of an Isokinetic exercise, where any speed of movement is impossible… there is again no resistance, and thus no exercise.

So there you have them, the unavoidable requirements for full-range form of exercise…

1-POSITIVE WORK

2-NEGATIVE WORK

3-ROTARY-FORM MOVEMENT

4-STRETCHING

5-PRE-STRETCHING

6-AUTOMATICALLY-VARIABLE RESISTANCE

7-BALANCED RESISTANCE

8-DIRECT RESISTANCE

9-RESISTANCE IN THE POSITION OF FULL MUSCULAR CONTRACTION

10-UNLIMITED SPEED OF MOVEMENT

Utterly ridiculous claims are being widely advertised for a number of forms of exercise… and almost all such exercises are supposedly full-range exercises; but the facts of the matter are simple enough for almost anybody to understand… and when the facts are understood, then the claims can be seen in a proper perspective. If an exercise is lacking any one of the above ten requirements, then it is not a full-range exercise… regardless of the claims of its promoters.

When… AND ONLY WHEN… all of these requirements for full-range exercise are clearly understood, and applied in a practical fashion, it becomes possible to provide a form of exercise that involves all of a muscular structure, and all of the related body parts, the joints and the connective tissue, and the bones.

Such ‘total’ exercise is capable of producing a rate of growth and a level of strength that cannot be duplicated in any other fashion… because it is the only form of exercise that is tailored to the requirements and limitations of the body itself.

Muscular mass and strength can be developed to the limits of individual potential… and having reached his own limit of ability, a particular subject may still not be as strong, or as fast, or as flexible as another individual; but he will be as strong as he can get, and as fast, and as flexible… which will be a lot stronger, considerably faster, and far more flexible than he would have been without such proper training.