Strength Training Modes

Nautilus: the Concept of Variable Resistance

By Nautilus Sports/Medical Industries

Since the inception of the NSCA Journal, several articles have presented various viewpoints explaining the Nautilus concepts of high-intensity exercise. It seems that a few strength coaches remain who still do not understand these guidelines and their implications for a properly executed conditioning regimen. The following discussion is designed to clarify the general principles of strength training.

Exercise is a process through which the body receives a message. This message alerts the body that its physical well-being is endangered. The body's interpretation of this message is that a modification or adaptive change is required in order to meet the demands of the environment and avoid physical insult. Exercise can and should be performed in a manner that is quite safe.

The improvement by the body as an indirect result of exercise is contingent upon several conditions. First, the necessary stimulus must occur. Second, the body must be provided adequate rest and nutrition to allow growth to occur.

The most important factor in exercise is **intensity.** Intensity is defined as the momentary percentage of maximum effort.

Activities that are perceived by the individual as easy are of low intensity. Low intensity activities can be continued almost endlessly, but they will not meaningfully stimulate the body to improve muscular strength. Since being easy, the body perceives no justification for demanding enhanced strength.

Low-intensity activity, if carried to extremes, does consume significant quantities of the body's nutrients. These nutrients are not immediately replaceable simply through eating. Their replacement requires time and rest as the body can process ingested nutrients only so fast.

Exercise, therefore, must be hard, or difficult, and it must be limited in quantity. It must be intense enough to provide the growth stimulus, yet its duration must be such that it does not prevent the growth it stimulates by consumption of those needed nutrients at the cellular level.

Researchers at Nautilus have examined the relationship between intensity and exercise duration and frequency since the late 1930's. Nautilus began with one important truth: **Most exercise is not performed with the required intensity to produce the necessary stimulus for eliciting growth.** Nautilus then began a careful examination of the relationship between the intensity and the rest required for maximum benefit.

A dramatic difference in the rate of beneficial results was noted when training subjects reduced the number of properly performed sets (of approximately 20 exercises) from four sets to two sets (three times weekly, every other day). Even more dramatic was the rate increase noted later when the same subjects reduced from two sets to one set of twenty exercises. Even faster improvements were seen with one set of fifteen exercises and then only ten to twelve exercises performed. Most of these comparisons were noted with the only meaningful exercise tool that existed then: the barbell. And it was well understood that as intensity increased, the quantity or duration of work was required to decrease.

Concurrent with the evaluation of the optimal number of sets per exer-

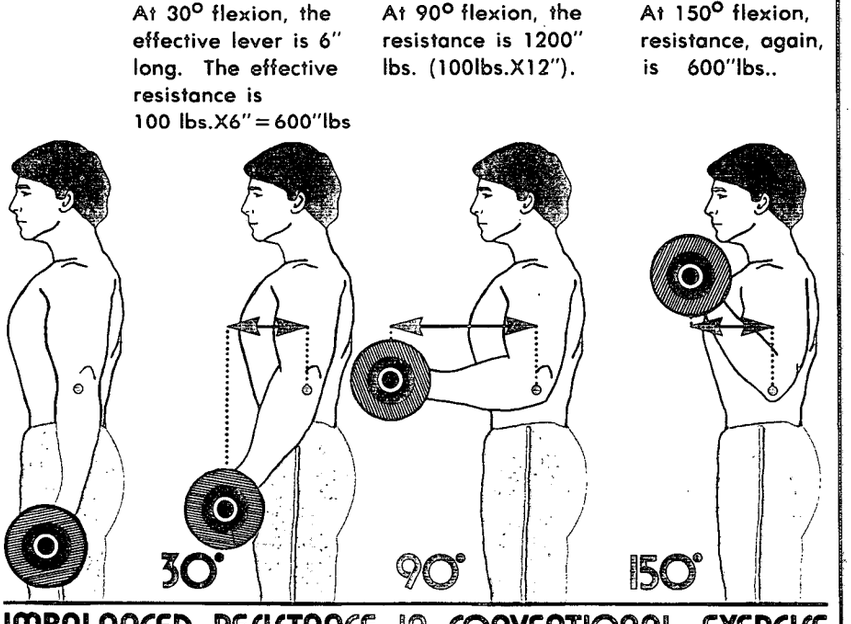

Figure 1. Imbalanced Resistance in Conventional Exercise

In the sequence above, assume that the barbell weighs 100 lbs. Since the first frame depicts the arm in a nearly straightened position, resistance is at or near zero.

Assume that the distance from the elbow to the barbell handle is 12". If so, then effective leverage is the length of a line drawn perpendicular from the line of gravity acting upon the barbell handle to a vertical line through the elbow.

The successive frames illustrate changing resistance resulting from a random lever. A random lever is responsible for the disproportionate resistance variation found in most conventional exercise tools. A random lever makes balanced resistance and full-range exercise an impossibility.

cise and the length of the daily workout (duration), Nautilus monitored the workouts of thousands of trainees in order to establish the minimum and maximum limits of optimal rest between workouts (frequency). It was found that forty-eight hours rest is minimally required for complete recovery between workouts. Seventy-two hours rest was often superior for advanced trainees. At ninety-six hours rest slight atrophy and weakening was noticeable. It is therefore reasonable to assume that the body requires a minimum of forty-eight hours rest between properly executed workouts.

Note **the body** in the preceding sentence. Many strength coaches favor the split routine—upper body on Monday, Wednesday, Friday; lower body work on Tuesday, Thursday, Saturday. The body exercises as a unit, eats as a unit, sleeps and rests as a unit. The required forty-eight hours rest pertains to the entire body, not just isolated body parts.

Almost simultaneously with the development of the proper method and protocol, came the evolution of a new tool: the Nautilus machine.

Nautilus, as noted earlier, realized that exercise must be hard. The barbell could provide the hardest form of resistance training known to man before 1948. Attempts toward intense exercise before the barbell included gymnastics, Indian clubs, and calisthenics. But with changeable plates, the barbell became the tool of choice.

One of the first clues gained by Nautilus researchers was the importance of intensity. This was a direct result of studying the effects of performing heavy barbell squats. The barbell squat was the single best exercise for increasing muscular mass throughout the entire body. It was also a hated exercise. Many weight enthusiasts were quick to spread rumors about the supposed dangers of squatting. It so happens that its effects, the rumors, and its low popularity ratings as an exercise were all related to one factor: barbell squats were **brutally hard.** Squats were so hard that most people preferred to spread rumors about their supposed dangers to justify excluding them from their exercise programs.

Any exercise **performed improperly** is dangerous. Though squats were indeed one excellent exercise, squats and **all** other conventional barbell movements worked only part of the muscle(s) involved.

The accompanying diagram depicts a simple barbell curl performed for the brachial biceps. It shows that although the barbell may weigh 100 pounds in the starting position, the effective resistance upon the biceps is zero, or nearly zero, due to the lack of what is known as lever, or moment arm. Only as the elbow approaches 90° flexion is any meaningful resistance imparted to the biceps muscle. And as the movement moves in either possible direction away from 90°, the resistance falls off disproportionately to the muscle's potential strength. Such deficiencies in quality resistance exist in all barbell and conventional machine exercises.

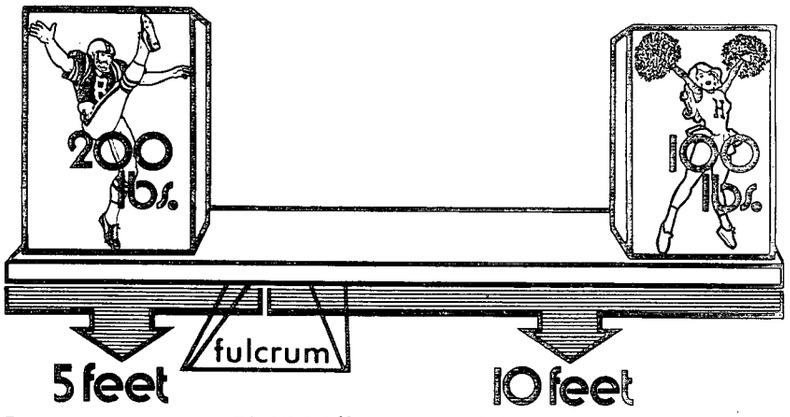

Figure 2. The Nautilus Cam

The problem of providing full-range exercise was solved by incorporating a cam. A cam is simply an "offround" wheel with a non-central axis of rotation.

The radius of a cam changes as it turns. The Nautilus cam can be thought of as an automatically variable lever that provides greater resistance or mechanical disadvantage where the trainee is potentially stronger and less resistance or mechanical advantage where the trainee is potentially weaker.

Lever advantage and disadvantage provided by the cam is similar to that found in a see-saw where the fulcrum is moved in order to balance differently weighted individuals.

The key word is *balance.* The Nautilus cam balances the provided resistance against the muscle's potential strength in each position throughout the muscle's full-range of functional motion. In this way, the Nautilus cam provides full-range exercise.

Now certainly, the biceps is much stronger than zero in the fully extended position of the elbow. And if the resistance provided by the barbell is not perfectly balanced to the strength potential of the muscle, then it follows that the resistance used will be limited by what the subject can handle in his weakest position.

Nautilus realized that the barbell, especially in the performance of squats, was an efficient tool for increasing strength and muscular size because it provided high-intensity work. Nautilus at the same time, however, realized that the barbell provided the **required intensity** to only a very small part of the working muscle.

PROBLEM: **What would be the effect if a device could be designed to require hard muscular work from the entire length of a muscle as opposed to a small fraction of that length?** Nautilus first reflected upon this question in 1948, and since then the Nautilus machine has evolved to what it is today.

The key to overloading the muscle through the entire range of movement lies in matching the resistance offered by the machine to the capabilities of the muscle. Nautilus calls this "balanced resistance."

Every muscle that produces joint rotation possesses an ideal and unique strength curve. Nautilus cams are designed specifically for each machine to "balance" or match the "ideal and unique" strength curve of that movement's agonists.

Many years ago, the noted physiologist A. V. Hill showed that a frog muscle, removed and kept alive in a laboratory solution, was strongest when stretched to 120 percent of resting length. Countless writers have since taken Hill's work with an isolated muscle and extended his conclusions, incorrectly, to muscles in the body. Unless the biomechanical linkages allow it, muscles *in the hu-*

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man body do not express their greatest strength when stretched to 120 percent of resting length.

In fact, an ideal strength curve can be plotted for every muscle based on the angle of insertion and the joint articulation. As the moment arm increases, expressed strength increases. As moment arm decreases, expressed strength decreases. The Nautilus cam perfectly balances this ideal strength curve by changing its radius in direct relation to several impinging factors including the changing biomechanical moment arm.

The unique value of the Nautilus cam to the athlete is its ability to reverse the disproportional strength development seen with conventional equipment. Ongoing research at the Lake Helen laboratory consistantly shows the inefficient and unnatural strength curves produced by conventional training tools. The marked weakness expressed by the muscle at the extremes of the range of motion is reversed by Nautilus training. The strength curve, where classically peaked midway through movement (in arm flexion, for example), tends to rise and flatten. This translates to the muscle being conditioned to its biomechanical maximum at each and every point. No other existing tool can perform that task.

Nautilus learned that full-range exercise possessed nine undeniable requirements. Without direct resistance, rotary resistance, variable resistance, balanced resistance, resistance throughout the full range of possible motion, stretching, pre-stretching, negative work potential, and positive work potential, full-range exercise is an impossibility.

A Nautilus machine is merely a logical barbell. The most important factor in exercise for skeltal muscle and its supportive structure is the intensity of muscular work. And intensity is dependent upon the **quality** of the resistance provided by the tool. Note the word **provided** for it remains up to the trainee and his coach to make proper use of the resistance provided by the tool being used. Poor form or style of performance in exercise will compromise the resistance quality of any tool.

In order to build the Nautilus machine, a clear understanding of the requirements of exercise was necessary. The requirements of full-range exercise as manifested in a Nautilus machine and the Nautilus training principles are directly linked to observations and evaluations of the effects of conventional exercise, and specifically the barbell squat. In fact, early articles referred to the first Nautilus machine, the pullover, as the "upper body squat." To the squat, the barbell, and extensive research, Nautilus owes many insights that are now accessible to all strength coaches.

Please do not hesitate to phone (with no obligation other than an open mind) Nautilus Sports/Medical Industries—Research Division for guidelines, principles, and details for planning the best conditioning program that can be applied to your present equipment and specific sport. (Nautilus phone number: 904/228-2884). ⊙

Viewpoint

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Returning to my original displeasure with Yessis' "studied" opinion that I "don't understand what actually takes place in skill execution," I *never* disputed the need for, or the occurrence of, an eccentric contraction prior to maximal concentric contraction. In fact, during Yessis' visit to Lake Helen, we spent more than one hour discussing the *details* of the eccentric phase. I am totally confused as to how he can tell our readers that I do not understand or advocate eccentric pre-contraction. I *did* say, however, that I have never heard, in contemporary neuroscience, of a "speed of eccentric to concentric switching phenomenon" as Yessis describes it. The brain takes many factors into account in computing the optimal point of terminating the eccentric phase and beginning the concentric phase. Among these are body weight, velocity, and possibly acceleration-deceleration of eccentric movement, and centrally-represented concentric strength. No one, in any published report that I've ever seen on the use of eccentric pre-contractions, has ever posited a mysterious central nervous system "speed of switching phenomenon."

In the category of "let's break our athletes' bones so that they can learn to withstand bone-shattering forces" (or examine our ability to withstand 90 mph collisions by running our automobile into brick wall at 90 mph), Nautilus is vehemently opposed to the concept, espoused by Yessis (right side of p. 34) that athletes should be trained in such a criminal manner to supposedly prepare them to withstand potentially detrimental forces. To employ the overload principles here is to suggest that athletes should be subjected to forces even more dangerous than those experienced during performance. This is obviously not morally right, but is it at least *physiologically* justifiable? We feel strongly that it is *not*, in light of existing evidence.

Again calling upon a private definition, Yessis tells us that "strength . . . is exhibited in a slower manner and so can be considered aerobic . . . " (p. 34). Everyone I've ever spoken to or read in the field has considered strength and force as relatively synonymous, and maximal force/strength is absolutely *not* related to aerobic power. If you do more than 60-90 seconds worth of repetitions, you (on the average) have nearly exhausted your anaerobic capacity to fuel muscular contractions with ATP. You then begin to demand ATP from aerobic processing. Skeletal muscles generally have *at least* five seconds worth of *stored* ATP and phosphocreatine, and that means that any strength movement of five or fewer seconds is not only not aerobic, it's not even *anaerobic* (according to the Mathews and Fox system)! It is mistakes such as this, and the double confusion over watts and foot-pounds per second, that cast serious doubt on the Yessis arguments.

My final point is that I was not sufficiently clear in decrying worldwide reliance on "what the other guy is doing." I by no means meant to imply that we cannot learn from others. I did mean to warn against *blind* faith by awe struck observers of Russian or East German athletes. We need to bring our coaches to realize the critical importance of analyzing cause and effect. We should not stand in automatic awe of the Russians, or East Germans, or everyone with an M.D. or Ph.D. after his name. We are all humans and make mistakes. Remember that if nothing else. ⊙