The Future of Exercise
(1997 and Beyond)

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Misleading Testing Procedures

Space devoted to things that do not work is not wasted . . . on the contrary, learning is largely a process of elimination; until these failures are carefully examined and understood, our efforts may continue in a wrong direction.

The most common mistake has been the use of dynamic testing procedures, Which was sometimes rationalized on the grounds that dynamic strength is more relevant than static strength. But both static and dynamic tests of strength are actually tests of the same factor, an indirect measurement of the force of muscular contraction.

Error in Peak Torque

Confusion has resulted from attempts to monitor changes in strength by measuring peak torque; but even when measured accurately, changes in peak torque do not provide a meaningful picture of gains (or losses) in strength. Figure 1 demonstrates this point clearly.

Comparison of three subjects with the same level of strength in the flexed position, the usual position of peak torque; in the flexed position, their strength level varied by less than three percent. But very significant differences in strength exist in all other positions; subject A produced only 26 foot-pounds of torque in the extended position . . . B was nearly five times that strong in the same position, 125 foot-pounds . . . and C was much stronger than the other two, 343 foot-pounds.

Following their initial strength tests, these subjects were exercised with what we considered an appropriate level of resistance; based upon their tested level of fresh strength. In one case we guessed right, but in two cases our estimates were wrong. Subject B was given 200 foot-pounds of resistance for the exercise, and performed nine repetitions; so our estimate was correct in that case.

Subject A, given 150 foot-pounds of resistance, could not perform even one full-range movement; was forced to stop before reaching the midrange of movement. Weakness beyond that point prevented additional movement against the level of resistance provided. When the resistance was reduced to only 100 foot-pounds, he was able to produce full-range movement; but even with this low level of resistance, movement in the extended part of the range could be produced only with great difficulty.

Subject C, given 175 foot-pounds of resistance, performed fifteen full-range movements; the resistance was too low. With 225 foot-pounds he would probably have performed nine or ten repetitions.

Trying to evaluate these three subjects by comparing their peak levels of torque, particularly if torque in the flexed position was compared, would be misleading. Judging their later progress by the change in peak torque would produce an understatement of their actual gains in strength. For any meaningful evaluation of spinal function, torque must be measured throughout a full range of movement.

fig. 1

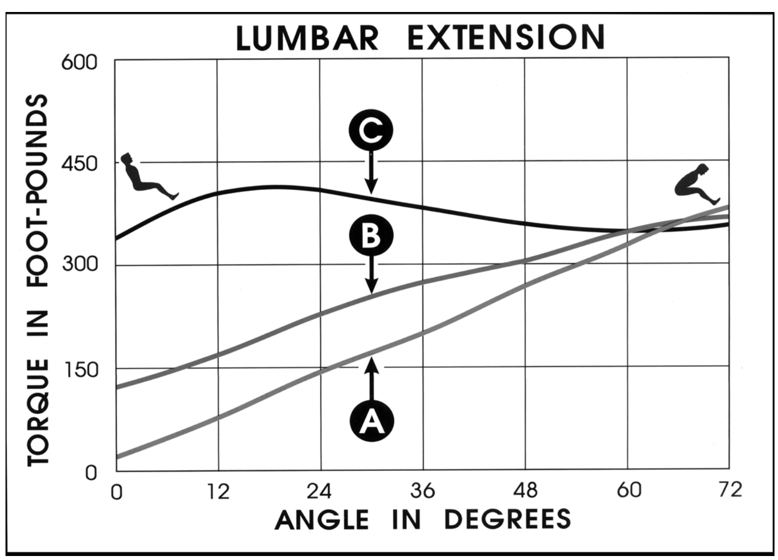
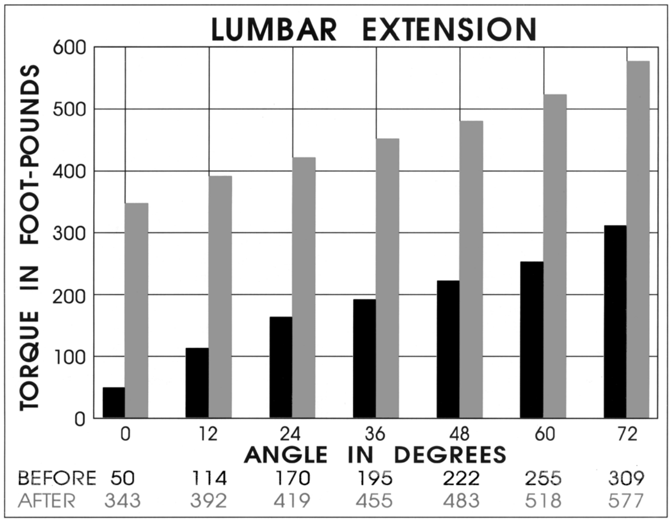


fig. 2



Subject C, in the fully extended position, was more than thirteen times as strong as A (343 compared to 26 foot-pounds); bringing subject A up to the same level in that position would require a gain in strength of 1,219 percent. But is such a gain in strength even possible? In our first study group of male subjects (all members of our research staff), two of these men increased their initial levels of strength in the fully-extended position to an even greater degree.

The potential for strength increases is largely determined by the initial level of strength; and when starting with the very low level shown by subject A in the extended position, the potential for gains in strength was enormous. But increasing his strength in the flexed position to the same degree would not be possible; in the flexed position, an increase of 80 percent is probably as much as could be reasonably expected.

Two of these subjects, B and C, were exercised and retested over a period of ten weeks following their initial tests shown above. Subject B increased his initial level of peak torque by 68 percent during that period; but evaluating his improvement by the change in peak strength would be misleading, because his strength in the fully extended position increased by 180 percent during the same period. And his full-range, dynamic strength increased 100 percent.

Subject C was initially strongest twenty degrees forward from full extension, and during the following ten weeks his strength in that position increased by 22 percent. But in the flexed position his strength increased by 60 percent, with a 33 percent gain in the fully-extended position; and with an increase of 60 percent in full-range, dynamic strength. With both subjects, their changes in peak torque were misleading; did not indicate their actual increases in strength.

Subject A was a physical therapist from Philadelphia, and was tested during a medical seminar in Florida, so was not available for later exercise and testing. A healthy male in his mid twenties, about six feet with a lean body weight of approximately 200 pounds, he had been exercising on a Cybex lower-back machines for several years prior to the test shown above; exercise that obviously did little or nothing to increase the strength of his lower-back muscles. Given his very low level of strength in the extended part of a full range of movement, it is almost certain that a few weeks of specific exercise would have increased his peak torque by at least 60 percent, while increasing strength in the fully-extended position by more than 1,000 percent. His full-range dynamic strength would probably have increased more than 300 percent.

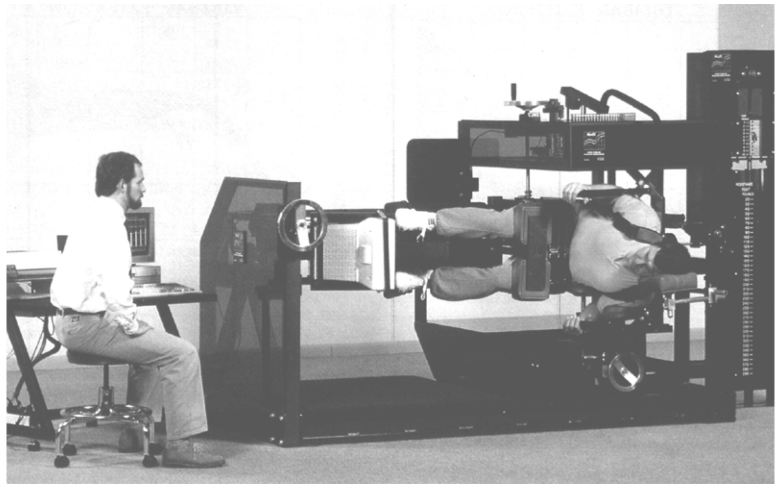
Research: During a six-month study, the average increase in peak torque produced by our first group of male subjects was 87 percent . . . but their average increase in a position of full extension of the lumbar spine was much greater . . . while the average overall change (area under the curve) was an increase of 142 percent (see fig. 2).

A later study with a large group of subjects, both male and female, was continued for a period of 20 weeks . . . with testing performed at the start, after 12 weeks, and after 20 weeks. Having produced large gains in spinal strength during the first 12 weeks of the study, during the last 8 weeks the average increase in peak torque was only one percent; but during that same period, strength in the extended position increased an average of 31 percent . . . very significant gains in strength that would have been overlooked if gains were judged by the change in peak torque.

A Faulty Assumption

It has been assumed, until recently, that tested functional torque is a result of the force of muscular contraction . . . and thus it was assumed that changes in functional strength were in proportion to changes in the strength of the involved muscles. But both assumptions are invalid.

fig. 3



Muscular strength is a result of only one factor, the force of muscular contraction.

But tested torque is a result of four factors; part of the torque may (or may not) be a result of muscular force, but it is not the only factor. Torque is also produced by the effect of gravity on the mass of the involved body parts, by stored energy, and by muscular friction if a dynamic test is involved. Until all of these factors are measured and considered in relation to tested torque, the results will be misleading at best.

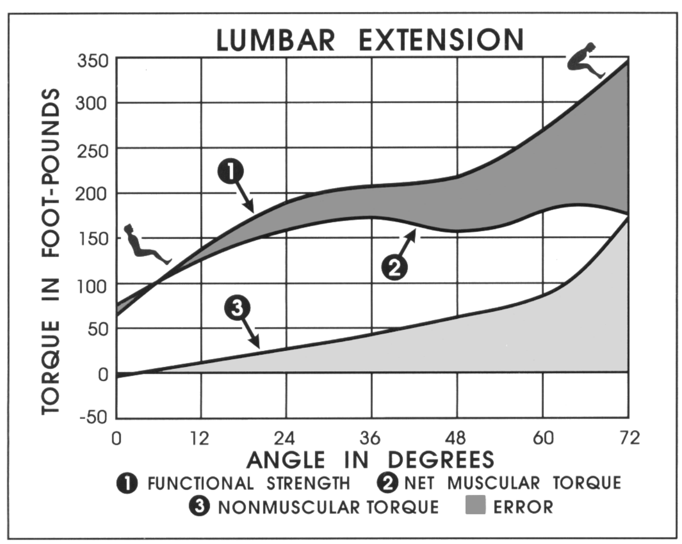
Figure 3: Primarily intended for clinical research, this version of the lumbar-extension machine provides both testing and exercise when rotated into a lateral position as illustrated above; a position which removes the usual effects of gravity, so that torque from the subject's torso mass is not involved. Static tests performed in this manner are biased only by stored-energy torque; but in tests of lumbar-extension strength, stored energy torque is a very significant factor.

Moving into the flexed position of the lumbar spine will store energy by compressing tissues in the front and stretching tissues in the rear of the torso; this stored energy will then produce force in the direction of extension, and the resulting torque will be shown by the monitor as a bar graph, while the computer will record the exact level of torque. If a seated position produces so much stored-energy torque, then why not test upright like the B-200 of the Cybex? Because unwanted pelvic movement cannot be prevented in a standing position; so tests in that position are misleading, regardless of now they are conducted.

If the fresh corpse of a large, dead man was restrained in this machine in the lateral position shown above, with the body pulled into a position of full flexion of the lumbar spine, then the output of torque might exceed 300 foot-pounds; torque that obviously would not be a result of muscular contraction.

Testing in an upright position, without proper counterweighting, where the effects of torso-mass torque would also be involved, the results would be more misleading.

fig. 4



With a living subject, tested in any dynamic fashion, where the effects of friction and impact forces would be added, the test results would have no relationship with true strength.

These nonmuscluar factors are not minor considerations that can be safely ignored during testing procedures. For meaningful test results, true muscular strength must be measured: the torque actually produced by the force of muscular contraction, Net Muscular Torque, NMT. In order to determine NMT, all nonmascular factors must be measured and considered in relation to the levels of tested torque.

Figure 4 shows the results produced by a test of isolated lumbar-extension strength, functional strength, compared to a test of true muscular strength, NMT. The highest curve shows functional

fig. 5

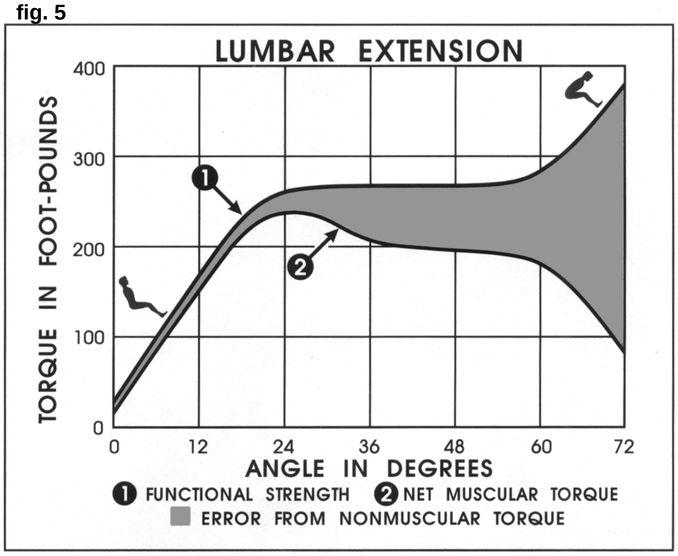
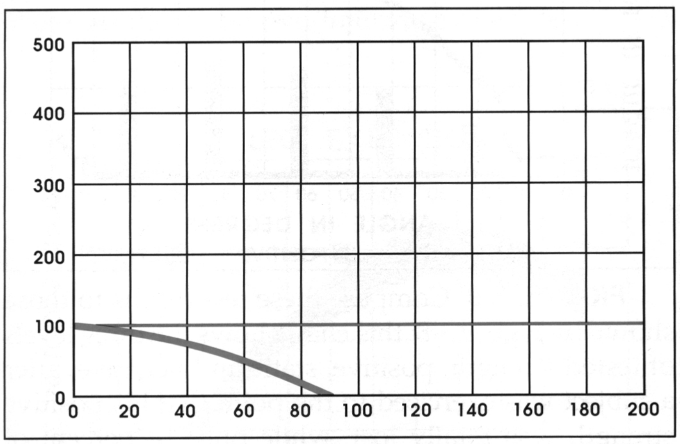


fig. 6



strength, the middle curve shows true strength, NMT, and the lowest curve shows the torque produced by stored energy. The red area between the highest curve and the middle curve shows the error introduced if stored energy was not considered; while the lower, blue area shows torque resulting from stored energy. A failure to consider stored energy in this case would lead to an overstatement of true strength in the flexed position of nearly 100 percent, with a slight understatement of true strength in the extended position.

These results were produced by a member of our initial group of tests subjects; five months later, following a program of specific exercise, he showed a gain in functional strength of 101 percent in the flexed position, together with a gain of 450 percent in the extended position. But his true gains in strength, changes in NMT, were 196 percent in the flexed position and 440 percent in the extended position. With symptomatic subjects, the error from nonmuscluar torque may be even worse; as demonstrated by the following example.

Figure 5 shows a patient with a twelve-year history of chronic lower-back pain; a big man, six feet, four inches, with a body weight of 260 pounds. The highest curve shows the level of fresh functional strength, while the lower curve shows true muscular strength, NMT. The red area between the curves represents error in test results produced by stored energy. Following eleven weeks of rehabilitation, his functional strength in the flexed position was 75 percent higher than the level shown here . . . but his true increase in that position was more than 353 percent.

Evaluation during rehabilitation must be based upon changes in true strength, NMT; changes in functional strength are grossly misleading.

It would probably be too much to expect most people to perform calculations in an effort to measure true strength; so the measurements of nonmuscluar torque must be performed by the testing equipment, and the calculations done by the computer, with the test results presented to the therapist as an accurate measurement of true strength, unbiased by any nonmuscluar factor . . . strength produced only by the forces of muscular contraction.

Impact Forces

In addition to misleading test results, any dynamic mode of testing unavoidably exposes the subject to high levels of impact force; a subject may produce only 100 pounds of force but be exposed to 500 pounds of force, or more.

With static testing, the force actually produced is almost exactly the same as the force imposed upon the subject. Some low level of impact force is unavoidable even in static tests; but if static tests are properly performed, the imposed force should not be more than one or two percent above the force produced by the subject. During rehabilitation, dealing as you usually are with an already damaged joint, the last thing you should be doing is imposing high levels of unrequired force during either testing or exercise . . . on the contrary, force should be as low as possible consistent with the requirements; if not, you may determine the limits of structural strength by producing an injury.

Figure 6: Using an isokinetic machine (Cybex), if a known level of 100 foot-pounds of torque was imposed, and if the machine moved through a range of 90 degrees, this is the exact curve of torque that should be recorded.

Figure 7: But when a known torque was imposed upon a Cybex isokinetic machine, and permitted to move through a range of 90 degrees, this is the actual result. This is not a measurement of torque, instead shows the results of impact force produced by the rapidly changing speed of the machine. This machine does not, as is claimed, provide a constant speed of movement; instead, the speed varies by several hundred percent, from far below the selected speed to far above the selected speed; with the resulting impact forces recorded here.

Figure 8: Electronic damping of the force measurements distorts the actual test result until it looks like the curve shown here; with no relationship to either what should have happened (Figure 6), or what did happen (Figure 7), and the actual range of 90 degrees was changed to an indicated range of 183 degrees. These examples were produced by tests with a Cybex isokinetic machine; and several studies have been published in a number of scientific journals during the last few years showing similar results.

Following examples clearly illustrate several other problems produced by dynamic test procedures.

Errors from Muscular Friction

Another source of error in all dynamic tests is produced by muscular friction; an important factor that has been ignored or overlooked by many people in this field. But if ignored, the error introduced by friction makes it impossible to produce meaningful tests results.

fig. 7

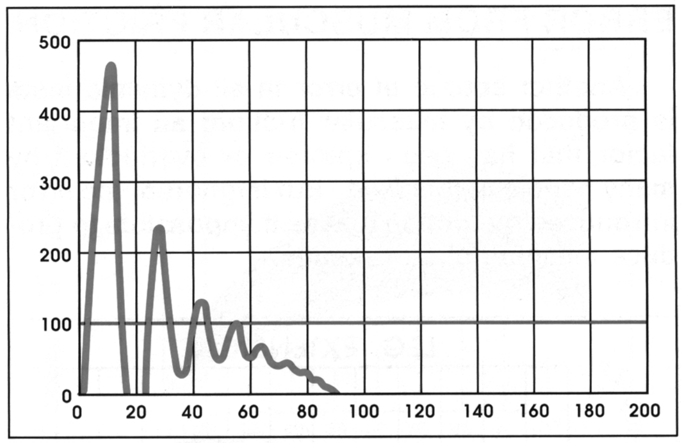


fig. 8

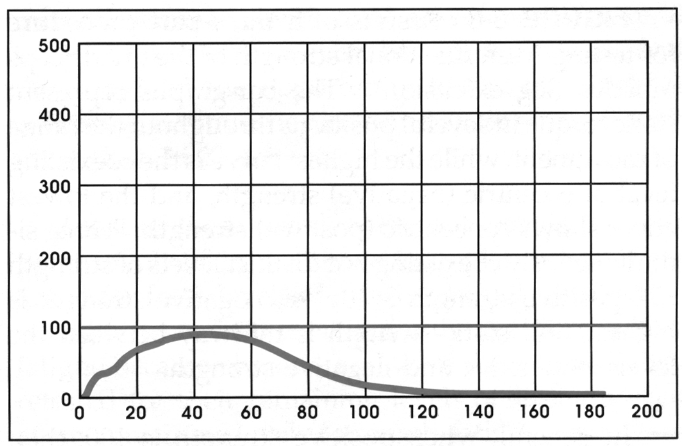


fig. 9

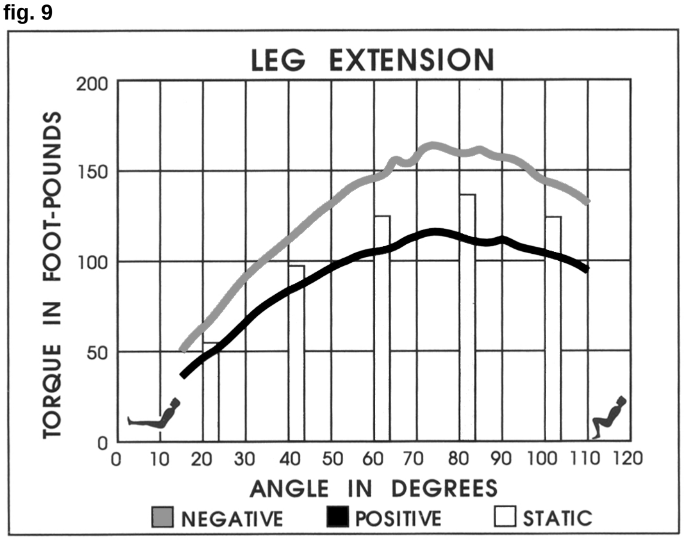


Figure 9: Results of a three-part procedure for testing fresh functional strength of the quadriceps muscles (leg extension). The bar graphs represent static torque in several positions throughout the range of movement, while the highest curve is the coexisting level of eccentric (negative) strength, and the lowest curve shows concentric (positive) strength. Three simultaneously coexisting but distinct levels of strength . . . positive strength is lowest, negative strength is highest, and static strength is midway between the levels of positive and negative strength.

fig. 10

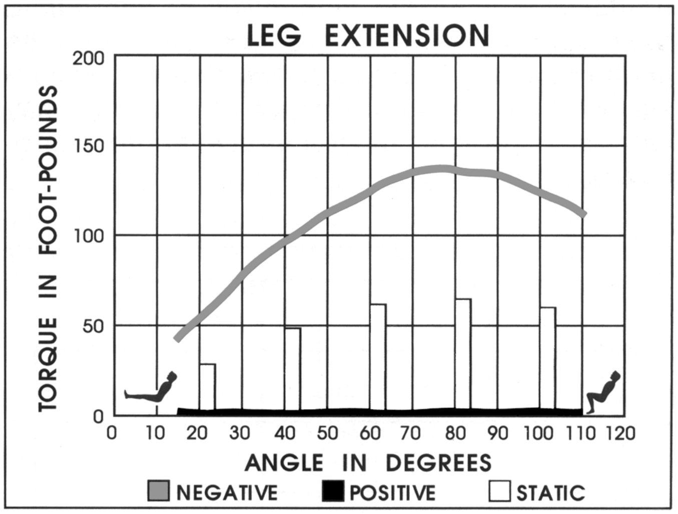
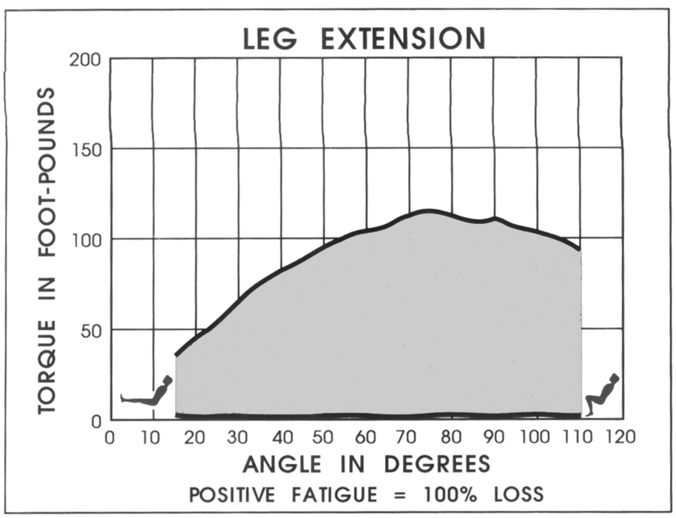


fig. 11



In general, when positive strength is 100, then negative strength will be 140 (40 percent higher), and static strength will be 120, midway between positive and negative levels. Assuming that you are testing fresh, rested muscles, at any level of strength, and that the dynamic tests are conducted at a relatively slow speed of movement. Fatigued muscles show a far different ratio, and tests conducted at faster speeds during the dynamic portions show a different ratio. But regardless of the level of fatigue, and regardless of the speed during the dynamic testing procedures, static strength will be midway between the positive and negative strength levels. Assuming that the same speed is used during both dynamic tests.

Static procedures provide the only meaningful test of strength . . . dynamic tests, regardless of how they are conducted, produce only artifacts; tell nothing about the true level of strength.

Tests of positive strength are always an understatement of true strength, reduced by friction in the muscles, while negative tests produce an overstatement of true strength, increased by muscular friction. If the level of friction was known, then perhaps meaningful results could be produced by adding to a test of positive strength, or by subtracting from a negative test . . . but the level of friction, as a percentage of muscular force, changes as a result of two factors, speed of muscular contraction and momentary level of fatigue.

Figure 10: Compare these test results to those shown by Figure 9, this chart shows the three levels of tested strength, positive, static and negative, after a subject was exercised to the point that his positive strength was totally lost, while only 14 percent of his negative strength was gone, and while his true loss of strength was shown by his remaining level of static strength, reduced by 50 percent from its fresh level.

Figure 11: The level of fresh strength measured during a test of dynamic positive strength, compared to the level of remaining strength following a very hard exercise, an exercise continued to a point where the subject could no longer produce movement even with no resistance against such movement. His loss of fresh positive strength was 100 percent. The red area between the fresh and exhausted curves shows positive fatigue from the exercise. Compare these results to the two following examples.

Figure 12: Tested for fresh negative strength prior to the exercise, the subject produced the highest curve of torque; when retested immediately after the exercise, produced the lower curve. The red area between the two curves shows negative fatigue from the exercise.

Figure 13: The actual losses of fresh strength were clearly indicated by the tests of static strength shown here. Positive tests grossly overstate the loss of fresh strength from exercise, while negative tests understate the true level of fatigue from exercise. But static tests will show what actually occurred. The shaded area between the two curves shows static fatigue.

fig. 12

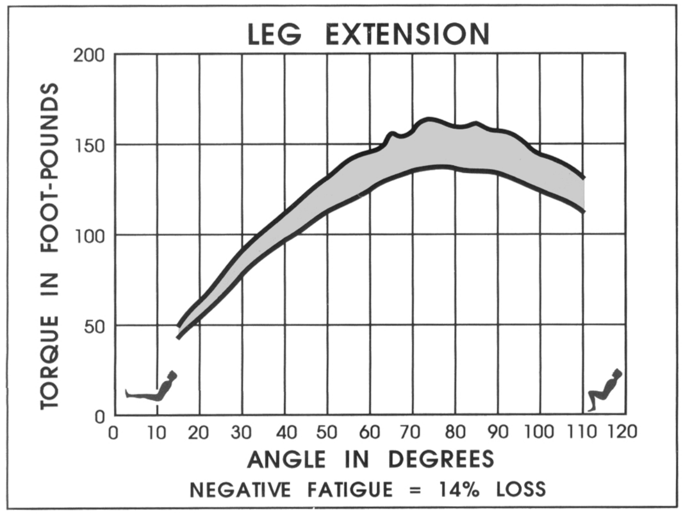
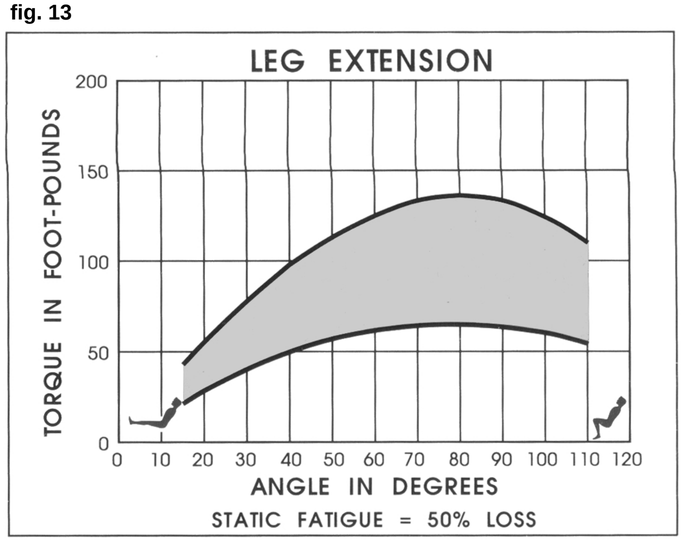


fig. 13



In 1985 and 1986, we conducted more than 200 medical seminars, with total attendance of several thousand people from every branch of medicine, and this provided the opportunity to test the levels of coexisting positive, negative and static strength with more than 2,000 subjects.

Most of these people were not exercised to the point involved in the above examples; instead were tested for their fresh levels of positive, negative and static strength, were then exercised only to a point where fatigue became obvious, and were then immediately retested for their remaining levels of strength. But at any remaining level of strength, fatigue was always overstated by the positive tests, understated by the negative tests, and accurately measured only by the static tests.

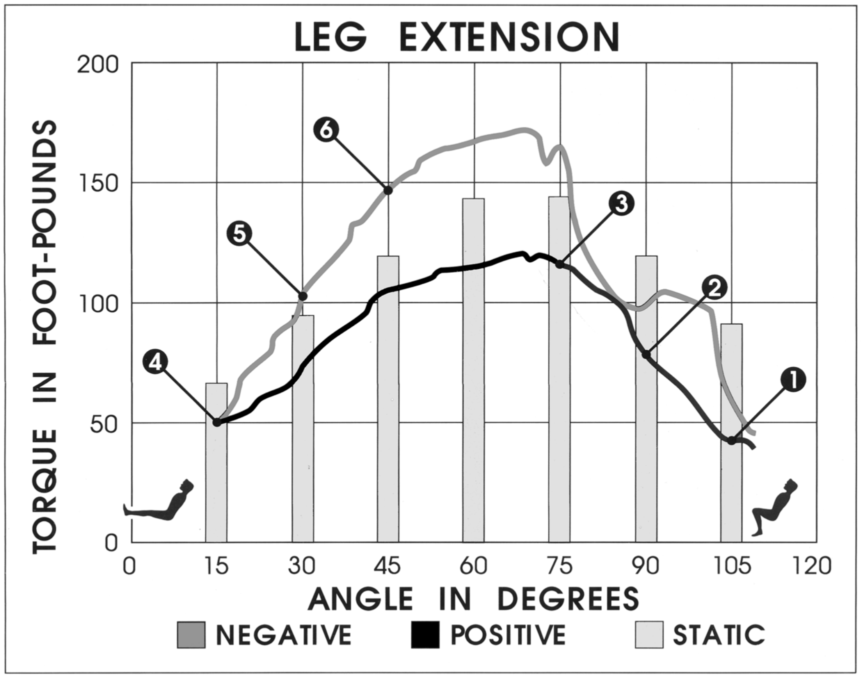
Even fresh levels of dynamic strength are biased by muscular friction, but the initial level of friction found in fresh muscles changes as fatigue is produced. When worked to a point where all of the fresh level of positive strength has been lost, the friction has then reached such a high level that it is equal to the force of maximal muscular contraction. Continued positive movement then becomes momentarily impossible; even though the actual level of fresh strength (force of muscular contraction) has been reduced by only fifty percent.

The following example demonstrates both physiological and psychological sources of error involved in dynamic testing procedures.

Figure 14: Look first at the right side of the chart, notice that the lowest line which represents the positive strength curve indicates a positive strength less than half of the static strength in that position. There is a dot in the static-strength bar-graph which represents positive strength in that position, a dot with an arrow pointing towards it, an arrow numbered 1 inside a circle. In that position, the positive strength should be about 83 percent of the static strength, but in fact was less than 50 percent.

This low level of positive strength in that position was produced by a factor which introduces error into all dynamic test results, the inability of the subject to recruit all of the available fibers instantly. In a dynamic test, the movement starts instantly, but you cannot recruit all of your available muscular fibers instantly; will move well away from the starting position before the muscle is capable of producing its maximum level of torque in that position.

fig. 14



Now look at the dot in the next bar-graph to the left. Having moved that far from the starting position, the subject was still not producing an appropriate level of positive torque, was producing only about 70 percent of his static level of strength in that position, when he should have been producing above 83 percent.

By the time he reached the position represented by the third bar-graph, he was finally producing an appropriate level of positive torque; but during the first 35 degrees of movement his measured level of positive strength was too low. He could not recruit all of his muscular fibers quickly enough to produce a true test of positive strength in those positions.

Throughout the remainder of the positive test, his measured levels of strength stayed fairly close to what they should be as a percent of his static strength in those positions. But at the end of the tested range of movement he was starting to show an effect from another factor: he was losing strength as a result of fatigue. The positive repetition required about four seconds to perform, moving at a speed of 25 degrees per second throughout a range of approximately 100 degrees; and because of the continuous nature of the test procedure he was starting to lose strength from the onset of fatigue.

In general, subjects with a high percentage of fast-twitch fibers will recruit rapidly but will also fatigue quickly; whereas subjects with a high percentage of slow-twitch fibers will recruit more slowly but will not fatigue as quickly. Most subjects will suffer primarily from one factor or the other, but generally not from both; will produce strength curves that are too low on one end of the movement or the other, but not to a marked degree on both ends. This subject recruited slowly but did not fatigue very rapidly; indicating a high percentage of slow-twitch fibers in these muscles.

Having moved across the chart from right to left, following the progress of the positive strength test, look now at the point where we ended the positive test, the dot numbered 4 being both the ending point for the positive test and the starting point for the negative test. Moving now left to right, follow the grey line that represents the strength curve during the negative dynamic test; notice first that the level of negative strength indicated in the starting position was far too low. Again the recruitment factor was responsible for a low test result; movement started and proceeded long before the subject could recruit all of the available fibers.

Follow the top line up to the position marked as number 5; having moved 15 degrees from the starting position, he was still producing far too little torque. This subject did not start to produce an appropriate level of negative torque until he reached a position about a third of the way through the entire range of tested movement, marked as number 6. His tested results were too low during the first third of the movement. Again a meaningless result . . . or worse, a misleading result. Then, during a large part of the rest of the tested range of movement, his results were compromised by another factor; but not a physiological factor in this case. Seeing the high levels of torque that he was producing, the subject backed off in his efforts . . . stopped trying to produce as much torque as possible. His tested levels of negative strength throughout the remainder of the procedure were far too low.

Until the additional errors produced by impact forces, body-mass torque and stored-energy torque are factored into the test results, any meaningful relationship between tested torque and true muscular strength is impossible. But it is also impossible to measure these factors during any form of dynamic test.

Twenty-eight years ago, then providing no negative work with their machine, the promoters of isokinetic exercise went to great lengths in their attempts to label negative work as both worthless and dangerous. As a result of this campaign against negative work, some people still avoid it during rehabilitation. Avoid it to their great loss, because negative work is certainly one of the most important parts of exercise.

During the period of sixteen years that Nautilus Sports/Medical Industries, Inc., was owned and directed by me, several teams of highly-qualified people worked for ten years in continuous efforts to produce safe, meaningful, isokinetic testing machines based upon servo-power; and one team, headed by Lester Organ, M.D., produced the first servo-powered machine ever built for this purpose; but this machine was never offered for sale, although we used it for research purposes for several years, with thousands of subjects.

Was not offered for sale because it proved to be unavoidably dangerous; the longer we worked with it the better we understood the problems with such technology. Several of the previously-used illustrations were produced by this servo-powered, isokinetic machine, and we learned a number of things from its use; but primarily learned that the related problems would not permit us to place it on the market.

We settled upon static testing for the good and simple reason that no other method works; static testing is far more than the best method of testing strength, it is quite literally the only meaningful method of testing strength.

Negative-Accentuated Exercise

Proper exercise stimulates increases in both muscular size and strength; but we still do not know exactly why this happens, or how it occurs. But it appears that two factors are involved: the level of fatigue produced by the exercise and the time required to produce that level of fatigue. Within reasonable limits, a higher level of fatigue is better, but only if it can be produced within a short period of time.

In 1972, then having no opinion regarding the relative merits of positive and negative work during exercise, we conducted a research program to determine the results of negative-only exercise, a style of exercise that involved no positive work of any kind. Using barbells and Nautilus machines, the lifting part of the exercise was performed by several assistants; so that the subject being worked could then perform only the lowering part of the exercise, the negative part of the work. For example, in a bench-press exercise with a barbell, two helpers lifted the barbell into position above the subject's chest, with no help from the subject; and when the helpers released the barbell in the top position, the subject slowly lowered it until reaching the lowest position, with the barbell then touching his chest. Whereupon, the helpers lifted it again, and the subject lowered it again, and so on; the helpers doing all of the positive work while the subject did all of the negative work.

Note: With a few exceptions, this is usually not a practical form of exercise, since it requires help; and it is unavoidably a dangerous style of exercise, since the assistants may release the weight before the subject is expecting them to . . . in which case the weight will fall and the subject may be injured.

But we were very careful and no injuries were produced; and our interest was limited to the value of pure negative work.

Each exercise was stopped when the subject started to lose control of the weight . . . when the speed of downwards movement started to increase, and when the subject could not prevent this increase in speed. When eight or more repetitions could be performed while still controlling the speed of downwards movement, the resistance was increased. And we quickly learned that only one set of each exercise was required, and only two weekly training sessions; more than one set of each exercise, or more than two weekly workouts, produced so much fatigue that the subjects could not fully recover between workouts.

The subjects in this study included high-school football players, two professional football players, and several advanced bodybuilders; all subjects being far above an average level of strength at the start of the program. Continued for a period of three months, this style of training produced better results than any form of exercise we had tried previously.

We did not then understand why the results were so outstanding; but we do now. Because of the increase in muscular friction that comes with fatigue, friction that increases negative strength while reducing positive strength, we were producing levels of fatigue that would be impossible to reach while performing any usual style of exercise. Impossible to reach within a reasonable length of time.

If your fresh level of strength is 100, and if you exercise with resistance of 80, then you will be forced to stop when your remaining strength drops below 80; your fresh strength will be reduced by about 21 percent. But if you immediately continued the exercise with resistance of 60, then you would fail when remaining strength was about 59, and if you then reduced the resistance to 40 in order to continue you would fail when remaining strength was only 39. If stopped at that point, you would have produced a high level of fatigue, but doing so would require approximately thirty repetitions of the exercise. The level of resulting fatigue would be good for the purpose of stimulating strength increases; but the amount of work required to produce that level of fatigue would not be good for the same purpose.

With the negative-only exercises outlined above, we were reducing the level of fresh strength by at least 80 percent, and were reaching that high level of fatigue within a relatively brief period of time. But this still left us with the unavoidable problems associated with a negative-only style of exercise, regardless of potential value, an exercise must be both practical and safe.

Problems that were eventually solved in the following manner: Negative-accentuated exercise provides the benefits of negative-only exercise, but without the problems.

Negative-accentuated exercise cannot be performed with a barbell, and cannot be performed during some exercises using weight machines, so it does not solve the problems in all cases; but it can be used in any exercise that involves both limbs working together. In a leg-press exercise, for example, the weight would be lifted by both legs, but would then be lowered by only one leg; both legs would share the positive part of the exercise, but only one leg would perform the negative part. Up with both legs, down with the right leg only, up with both legs again, down with the left leg only, and so on.

If your fresh strength using both legs was 100, you would normally exercise with resistance of 80, and would fail when you could no longer lift the weight with both legs, would fail with a remaining strength of about 79. But with a negative-accentuated style of training you would use a lower level of resistance; instead of 80 percent of fresh strength you would use only 50 percent. With a usual exercise using resistance of 80, each leg would lift, and lower, 40, but with negative-accentuated exercise, using resistance of 50, each leg would lift only 25, but would lower 50. Resistance would be lower during the positive work, but higher during the negative work.

Performed properly, at a slow speed, you will fail during the positive part of the exercise; will fail when both legs can no longer lift the weight. Having reduced your fresh positive strength by more than 50 percent; a level of fatigue far higher than the 21 percent loss of fresh strength produced in most exercises. But having failed to lift the weight with both legs, if somebody will lift it for you, then you can still lower the weight under full control with only one leg. Before the exercise your negative strength was 40 percent higher than your positive strength, but that ratio of negative to positive strength changes as a result of fatigue, changes because of an increase in muscular friction; friction that reduces positive strength while simultaneously increasing negative strength.

A negative-accentuated style of exercise can be used with the MedX knee machine, and may well provide the most productive form of exercise for the quadriceps muscles; but should not be performed more than twice a week with any subject, because of the high level of resulting fatigue.

Apart from the description above, the only additional information for proper performance of this style of exercise is related to the position in the exercise where the weight is shifted from both legs to one leg; this hand-off of the weight to one leg should be performed smoothly and slowly. Lift the weight to the top position with both legs, and pause in that position, with both legs fully extended, then slowly move one leg away from the resistance pad, so that the weight is then being held in the fully-extended position by only one leg.

Having carefully shifted the load to one leg, then slowly start to lower the weight using only one leg; the downwards speed of movement should be slow and steady; and if you cannot prevent an increase in the downwards speed of movement, then the resistance is too heavy. But with a proper level of resistance, together with the correct style of performance, failure will be produced when you can no longer lift the weight with both legs.

Negative-accentuated exercise is one of the safest styles of exercise, does not expose the subject to high levels of force from impact; but does produce the high level of fatigue required to stimulate increases in strength, and produces this level of fatigue within a brief period of time.

Note: Having observed the results we produced with a negative-only style of exercise during the research in 1972, coach Bill Bradford of the DeLand, Florida, high-school, then started a weightlifting team . . . and trained his athletes with negative-only exercise.

Starting competition in 1973, with no previous weightlifting experience, Bradford then established a record that is probably unprecedented in sports; his teams were untied and undefeated for a period of seven years of competition, won more than a hundred weightlifting competitions.