Testing Strength

The procedures that we are now using for the purpose of testing lumbar function are performed as follows; first, I will outline the method used for testing lumbar extension, and then the method for testing torso rotation. By far the two most important tests.

Extension

ONE. Disconnect the drive-sprocket of the machine to permit the resistance-pad to move freely without resistance. Time required, one second or less.

TWO. Seat the subject in the machine and tighten the three separate pelvic-restraint components; which can be accomplished in about thirty seconds or less.

THREE. Fasten chest strap. Time required, about five seconds.

FOUR. Restrain arms. Time required, two seconds.

FIVE. Restrain head. Time required, five seconds.

SIX. Disconnect torso-mass counterweight and move subject into a position of top-dead-center, in order to establish the center-line of his torso mass. Then reconnect torso-mass counterweight. Time required, ten seconds or less.

SEVEN. Have subject move to the rear position and relax. His level of body-mass torque in that position will be displayed in a digital read-out on the computer screen. Turn wheel on top of torso-mass counterweight until a reading of zero is produced on the computer screen; which means that the body-mass torque is now removed throughout a full range of possible movement. Time required, about fifteen seconds.

EIGHT. Ask subject to move slowly through a full range of possible movement and note the limits of safe travel; which data will be automatically recorded by the computer and simultaneously displayed on an external goniometer (range-of-movement indicator). Decide on the number and positions of the desired test points and punch this information into the computer. Together with each of the selected test points, you will also punch in a moment-arm correction factor . . . information supplied by the resistance-pad goniometer. But this must be done only once with any new subject; does not need to be repeated during later tests. Time required, about forty seconds the first time with a new subject and less time afterwards with the same subject.

NINE. Ask the subject to move to the most forward test position and then lock the machine in that position. Time required, about two seconds.

TEN. Instruct the subject to start exerting a force against the resistance-pad, slowly and carefully building up the level of force to the highest level that he is capable of producing in that position.

As the subject performs the test in the first position he should be instructed to watch the monitor, which will instantaneously display a bar graph representing the level of force that he is actually producing with his lumbar muscles . . . and will also display any slightest amount of impact forces as a red line rising above the actual level of force produced by the muscles. The subject will constantly be aware of this extra force and thus encouraged to perform the test in the safest manner possible.

Time required, about seven or eight seconds.

ELEVEN. When the subject has reached the highest level of force that they can produce in that position, they should gradually relax until they are producing no force against the pad. Time, two seconds.

TWELVE. Disconnect the movement-arm and have the subject move into the next test position and then re-lock the machine in that position. Repeat test in second position, as before. Time required, nine or ten seconds for each test position utilized.

While it is possible to test a flexible subject in a total of twenty-five different positions, at three-degree increments throughout a range of movement of seventy-two degrees, this is neither necessary nor desirable; in practice, tests performed in seven or eight positions will give you all of the information that is required.

From this information, the computer will immediately display and simultaneously start to print out a hard copy of the subject's lumbar-extension strength curve, accurately correlating strength versus position and calculating the area under the curve.

All of which procedures can be completed with a new subject in a total time of less than five minutes, if we assume eight test positions.

Then about fifteen seconds will be required for the subject to be removed from the machine . . . during which time the hard copy of the test results is being printed.

All of which presupposes a healthy subject; injured subjects will usually require a bit longer, depending upon the nature and degree of the problem. But even a near-paralyzed subject can be tested in well under ten minutes in almost all cases.

Following tests with the same subject require somewhat less time, primarily because the required torso-mass counterweight position and moment-arm correction factors are already established and recorded by the computer.

The resulting print-out of the subject's strength curve provides you with a lot of very valuable information of several kinds, some of which might not be obvious to people inexperienced with this equipment. Normal or subnormal range movement. Normal or abnormal strength curve. High, medium or low level of strength for a subject of either sex and any size and age. Type S or Type G classification with a high degree of probability in a previously untested subject. Type S subjects display a greater fall-off of strength as they near a position of full extension and this produces a very distinctive shape in the strength curve. Type G subjects have a much flatter strength curve.

With a bit of experience, it is possible to reach a fairly accurate opinion in regards to the fiber-type classification of the subject; but in doubtful cases a simple follow-up test will confirm or refute your initial impression in a very accurate manner. Which information is of great significance for the purpose of determining an appropriate program of exercise for any particular subject.

And . . . if there is any doubt in your mind about the validity of an apparent injury, a claimed injury, then this matter can be resolved by repeating the test a few minutes later; if the injury is real then the subject will duplicate the test results so closely that there is no slightest reason to doubt the claim . . . but if the injury is not real, then that point will also be resolved. Because, if the subject is attempting to fake an injury then they can do so in only one way, by holding-back during one or more of the test positions, by pretending to produce a maximum level of force while actually doing less than they could; which will certainly produce an abnormal strength curve, thereby making it appear that an injury is involved . . . but they cannot duplicate this curve during a second test. So both curves will be abnormal, but will not be even closely related; because, it is simply impossible for a subject to fake the results to the same degree during both tests.

Whereas, if the injury is real then the curves will be nearly identical.

The machine is almost a lie detector for claimed lumbar injuries.

All of which sounds rather complicated when outlined in print, but none of which is difficult to perform with the actual machine. In no sense is the equipment intimidating for either the subject or therapist.

During research programs we repeat the test procedures as often as necessary to insure that the subjects are giving us their best efforts, in order to establish a firm starting point for later comparison to identical tests performed a matter of several weeks later . . . to determine the progress, or lack of progress, of the subjects in response to a particular program of exercise; but this is seldom necessary with the majority of subjects that you will be testing . . . because, as they become familiar with the test procedures, and as they begin to look forward to their next test as a measurement of their progress, they will rather naturally start to give you their best efforts during the tests.

Being able to see the degree of improvement that is produced from test to later test is a very strong psychological spur to most subjects, and a consideration of no small consequence in itself.

Rotation

Testing for rotary-torso strength has a great deal in common with the protocol outlined above for the lumbar-extension test . . . with a few differences; but, everything considered, it is an easier test to perform. Primarily because the movement is a lateral movement . . . or, at least, a rotary movement performed in a lateral plane . . . and therefore does not require counterweighting of the subject, since there is no body-mass torque in a lateral plane.

Secondly, and for the same reason, there is no need to restrain either the head or the arms; pelvic restraint is just as important and is accomplished in the same manner, although in this instance we are restraining the pelvis to prevent pelvic rotation rather than pelvic tilting.

In this test it is necessary to restrain the shoulders so that the upper back remains in firm contact with the resistance pad, to prohibit rotation of the torso without an exactly equal degree of rotation of the resistance pad.

The range of movement is greater than it is in lumbar extension, and the strength curve in this movement is not at all like the strength curve produced by lumbar extension; but the actual testing procedure is almost identical.

There is, however, one significant point of great importance . . . the potential for improvement in strength in this movement is usually greater than that for any other muscular structure in the body; most normal subjects are capable of increasing their strength in this movement by several hundred percent, and can do so in a remarkably short period of time as a result of very little in the way of exercise.

Most subjects are very weak in this movement . . . at first; but are capable of an enormous degree of improvement. Primarily because there has never before been any meaningful form of exercise for these muscles, but also due to the fact that most day-to-day activities provide little or nothing in the way of work for these muscles. So the potential for a relatively high level of strength is certainly there, but seldom exists; and since these muscles are so important for helping to prevent lumbar injuries, it follows that they should be strengthened as much as possible. Which is easy to do now that we have a meaningful form of exercise.

Based upon tests of thousands of subjects, it appears that about eighty percent of them were Type S subjects, meaning that they produce a very specific response to exercise (see chapter eighteen). In the muscles which produce torso rotation, this means that the strength will be very low as the subject nears a position of full muscular contraction . . . at least initially; but only with Type S subjects. Type G subjects will be no stronger on the other end of the movement, but will be far stronger as they approach the position of full muscular contraction, several hundred percent stronger.

It has been widely assumed, in my opinion correctly assumed, that weakness of the torso rotational muscles is at least partly responsible for a fairly high percentage of lumbar injuries; probably because a weakness in these muscles permits an unusually high load to be imposed upon the lumbar-extension muscles in certain positions, usually when something is lifted while the torso is twisted to the side.

But there is the potential for another serious problem that I have seldom heard mentioned, a dangerous potential that most people do not seem to even be aware of, people who need to be aware of this situation; as I mentioned earlier in this book, for all practical purposes the lumbar vertebra do not rotate. Literally cannot rotate. Must not be forced to rotate because they are not designed to rotate. If rotation is forced in this area of the spine then injuries will be produced that are far more serious than strained muscles or torn ligaments . . . the facets of the vertebra themselves will break, literally must break because they are not capable of rotation to any meaningful degree.

Do not ever attempt to force rotation of the lumbar spine . . . stretching in this part of the body must be performed very slowly and with little or nothing in the way of a load that forces the subject to rotate.

The interlocking relationship of the lower spine, from T 11 through the sacrum, is such that very little rotation is even possible without serious damage to the vert^bra themselves . . . and published reports of rotation potential in this area are in my opinion overstated; so proceed with caution.

Range of movement in torso rotation will vary rather widely from one subject to another, and because of the consideration mentioned above it does not appear to be wise to attempt to increase this range of movement by stretching . . . rather than stretching the muscles you may find to your surprise that you are breaking the facets of the vertebra.

Previous attempts to measure lumbar spinal rotation have usually been wrong when living subjects were tested, probably because of a failure to note pelvic rotation which was then included in the published range of movement.

On a scale of zero to one hundred, in allocating benefits to be derived from proper exercise performed for the purpose of improving the strength of the lumbar area, I would rate both lumbar extension exercises and torso rotational exercises as one hundred; I believe they are equally important.

Conducting dynamic strength tests for these muscles is covered in detail in other chapters, so I will not cover them here. But will mention that many of the procedures are identical, since they involve the same factors that are requirements for any sort of meaningful and safe testing procedure.

Injury . . . Cause and Effect

For a period of nearly eight months, during part of 1985 and part of 1986, I conducted medical seminars on a seven day a week basis; during which seminars I talked with several thousand doctors and therapists, with a sprinkling of other people in related fields. Which experience made me aware of the general lack of meaningful information that exists among a group of people who should be dealing strictly with facts. But it does appear that a lot of people are looking for information, so maybe there is a ray of hope for the future.

I founded Nautilus Sports/Medical Industries, Inc., in 1970, after working in this field but with no commercial interest in this field for many years; and I sold that company as of June 16, 1986 . . . in order to devote my attention to the continued development of testing machines, primarily in the area of lumbar testing. But several years before I sold Nautilus, I employed a man named Lester Organ, a medical doctor who is also an engineer; a man who devoted his efforts for years in similar directions, sometimes on his own behalf and sometimes under contract to me. He then devoted all of his own time, the time of several other highly qualified people working under his direction, and several million dollars to a project to develop testing equipment for both quadriceps muscles and lumbar-extension muscles. The results of this project are certainly the best isokinetic machines ever produced, by far; but they are not a product that I would ever have put my name on . . . for a number of reasons.

Simultaneously, but totally apart from Dr. Organ's efforts, three other people directed similar projects; devoting many years of the time of highly qualified people, plus additional millions of dollars . . . and these projects also produced such machines, but nothing I would ever have considered selling.

During the eight months of daily medical seminars, we used the machine developed by Dr. Organ as one of our demonstration tools, together with a Cybex machine that I purchased about ten years ago and have worked with ever since; but we did not use either the Cybex machine or our own machine in any attempt to show the advantages of an isokinetic form of testing . . . quite the contrary, we used them for the opposite purpose, to demonstrate the many problems with such machines, and the dangers involved in the use of such machines.

Some of the test charts used to illustrate this book were made by using the machine developed by Dr. Organ, and we are still using that machine for research purposes; because it did serve a very valuable purpose . . . really two purposes.

Dr. Organ's machine provided me with the ability to prove something that I had known for years but had been unable to prove. It proved that the difference between positive and negative strength is a result of internal muscular friction . . . and thereby proved that its own dynamic tests were worthless for testing purposes.

Then this same machine went on to teach me something else, something that I should have realized earlier but failed to notice in spite of years of research with negative exercise; internal muscular friction increases as a result of fatigue.

While using a style of exercise called negative-accentuated exercise, the positive part of the work is shared by both limbs but the negative part is performed by only one limb; thus the resistance is twice as high during the negative work as it is during the positive work.

When you are unable to continue as a result of fatigue, you always fail during the positive part of the exercise; you fail because both limbs are then unable to lift the weight . . . but if the weight is lifted for you by somebody else, you can still continue with the negative work while using only one limb. At that point your negative strength is more than twice as high as your positive strength . . . this being proof that your negative/positive ratio of strength has changed from a starting ratio of 1.4 to 1 to a ratio in excess of 2 to 1.

How much does the ratio change?

To infinity, until your positive strength is zero while your negative strength is still more than eighty percent of its starting level.

Then, at that point, what is your real level of strength?

If the positive strength of a fresh muscle was 100, then the negative strength would be 140, and the static strength would be 120; but when exercise has been carried to a point where fatigue has removed all of the positive strength . . . then the fatigued levels will be as follows; positive strength will be zero, negative strength will be 120, and static strength will be 60. As always, static strength will be midway between the positive and negative levels.

The real level of starting strength would be reduced by only fifty percent, from 120 to 60 . . . while the positive level was reduced by one-hundred percent, from 100 to zero . . . and the negative level by only about fourteen percent, from 140 to 120.

A few minutes of consideration should make it obvious that any comparison of positive strength before an exercise to positive strength after an exercise is meaningless . . . tells you nothing about just how much the strength has been reduced; and the same is true in regard to negative tests before and after an exercise.

Once we understood what actually happens to a muscle as an immediate consequence of exercise, we also understood why negative exercise creates so much fatigue if overdone. By reducing your negative strength only fourteen percent you can reduce your positive strength to zero . . . and having done so it may take you two weeks to fully recover from such an exercise session; which is certainly overdoing it.

Which does not mean that negative exercise is either bad or dangerous in any sense. Quite the contrary, negative work is by far the most important part of exercise; for several reasons covered in other chapters.

Frequently, negative exercise is the only possible form of exercise for very weak subjects.

During the last few repetitions of an exercise continued to a point where your remaining level of positive strength is zero, the negative level of strength, having dropped quite a bit during earlier repetitions, then starts to rise again . . . as the positive level is dropping repetition by repetition, the negative level is increasing. But if you terminate the exercise at any point and immediately test the static strength, you will always find that it is exactly midway between positive and negative levels, at any level of fatigue.

We have confirmed this by conducting such tests with hundreds of subjects, and regardless of the point where the exercise is stopped, an immediate test of static strength will show a level midway between positive and negative levels.

Meaning that the very definition of fatigue is not valid; must be rethought, because a large part of the apparent loss in strength is actually not a loss of muscular strength in itself; is due to an increase in friction; the muscle is still producing a lot of force, but you are prevented from using it in positive work by the increase in friction, while the friction actually helps you in negative work.

So Dr. Organ's machine, while not suitable as a test machine for doctors or therapists, did serve as a teaching tool for us; in that sense it was worth the cost. It taught me something that I had noticed but failed to understand much earlier.

Over fourteen years ago, in 1973, we displayed three different models of testing machines based on a hydraulic principle . . . but we never tried to market such machines, because that approach is wrong, as careful tests of our own products clearly demonstrated. Over twelve years ago, in 1975, I published an article in The Athletic Journal that clearly spelled-out the concept of a computerized exercise and/or testing machine; but we never attempted to market them either, although several other people are marketing such equipment now, years later. We did not market them for several good reasons . . . primarily because the test results are meaningless, but also because of safety reasons.

We have been working on these concepts for a long time, and after devoting many years and millions of dollars to such research, when we did not rush into the marketplace with some product at the earliest possible opportunity . . . then you might be well advised to consider just why we waited so long.

Now I will outline the protocol that was used in the test that finally taught us just what happens to a muscle that is worked to the ultimate degree, or very close.

The subject was one of our own people, for two reasons . . . because we clearly understood that the test was dangerous, and because we required a subject that would accept the risk and be willing to continue until we told him to stop, regardless of the consequences.

Was the risk justifiable?

Well, people play football, don't they; is that risk justifiable?

Using the machine developed by Dr. Organ, we tested the subject at all three levels of strength; first he performed a positive strength test . . . next he performed a negative strength test . . . and finally he performed a static strength test. Both positive and negative tests being dynamic tests.

All of his efforts were displayed on the screen of the computer as they were being recorded . . . so the subject could see the results as he was making those efforts. The positive test was recorded as a blue curve moving across the screen from right to left . . . the negative test was recorded as a red curve moving across the screen from left to right . . . and the static tests were recorded as a series of bar graphs of a neutral color.

All three tests were then displayed on the screen . . . providing a graphic illustration of his three levels of functional strength on the same scale. His positive strength was the lowest, his negative strength was the highest, and his static strength, his real level of strength, was midway between positive and negative. Positive 100, static 120, negative 140.

Then the computer took his positive strength curve and created another curve which represented seventy percent of his positive strength . . . and this was displayed on the screen as a target for the test. The seventy-percent-of-positive curve being displayed as a heavy line curving across the screen.

Next the computer calculated and then displayed two other curves represented by thinner lines across the screen . . . a lower curve representing fifty-five percent of his positive strength, and a higher curve representing eight-five percent of his positive strength.

The subject was instructed to perform the exercise while attempting to maintain a force that was always seventy percent of his starting level of positive strength . . . he had just demonstrated a level of one-hundred percent, now we were merely asking him to do seventy percent. So he was strong enough to follow the instructions, both the positive and the negative efforts being sub-maximal efforts when he started the exercise.

But it was quickly apparent that he could not follow another part of the instructions . . . he could not keep his level of force on the target curve; which was not surprising, since it is impossible to do so in an isokinetic machine even when you are provided with instant feedback.

The exercise itself was dynamic, isokinetic and servo powered . . . that is, the movement-arm and attached resistance-pad were moved by the motor of the machine at an exact speed of 25 degrees per second, thus requiring about four seconds for each positive repetition and an equal time for each negative repetition. Range of movement was about 100 degrees. Muscles being tested were the quadriceps of one thigh.

The torque produced by his lower limb was determined by the machine prior to the initial tests and this information was utilized by the computer so that the results would not be biased by a failure to consider the mass of his lower limb and the resulting torque.

He was strapped into the machine as tightly as possible to prevent unwanted movement of the thigh . . . and his lower leg was strapped to the movement arm so that his leg would be moved by the machine even if he made no efforts at all.

His safe range of movement was determined in advance and the machine was locked so that it could not exceed this demonstrated range of safe movement.

He was instructed to perform as many repetitions as possible while maintaining a level of force equal to the curve displayed on the screen . . . not too much effort and not too little effort.

But once it was necessary for him to perform at a maximal level in order to reach the target level during the positive part of the exercise . . . then the exercise became a maximum-possible test. Then he started working as hard as possible during both parts of the exercise. Such maximum effort was first produced during the eleventh repetition, and then during all following repetitions.

Once he started working as hard as possible, his positive level of strength dropped steadily and rather rapidly from repetition to repetition . . . while his negative level of strength climbed. He was steadily losing positive strength while gaining negative strength, simultaneously.

When his positive strength had dropped almost to zero his negative strength was still increasing.

Surprising?

It shouldn't have been, but it was; we should have expected it, but we didn't.

During the last repetition, his positive strength was only 2.1 percent of his starting level of positive strength, meaning that he had lost 97.9 percent of his positive strength . . . while the last negative repetition performed, immediately following the last positive repetition, demonstrated a negative strength of 121.1 percent.

Prior to the exercise, it was established by his initial strength tests of the fresh muscle that his negative/positive ratio was 1.4 to 1, meaning that his negative strength was forty percent greater than his positive strength. But at the end of the exercise this ratio had changed to an almost unbelievable degree . . . his ending ratio being 57 to 1; meaning that his negative strength was fifty-seven times as high as his positive strength.

So just what was his actual strength at the end?

Just over sixty percent of his starting level of positive strength. Midway between his positive level at the end and his negative level at the end . . . as it must be, since that is always the actual level of strength.

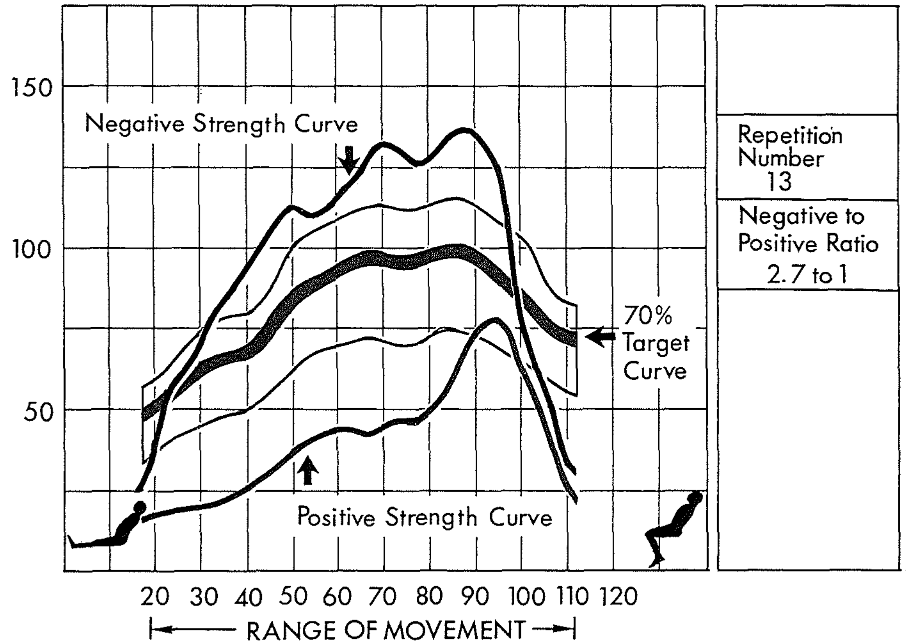
The charts opposite provide a clear presentation of what occurred during four of the repetitions performed during the test described earlier. On the upper left-hand side of the page is a chart of the 13th repetition, which was the third maximum-effort during the test. All of the first ten repetitions having been submaximal.

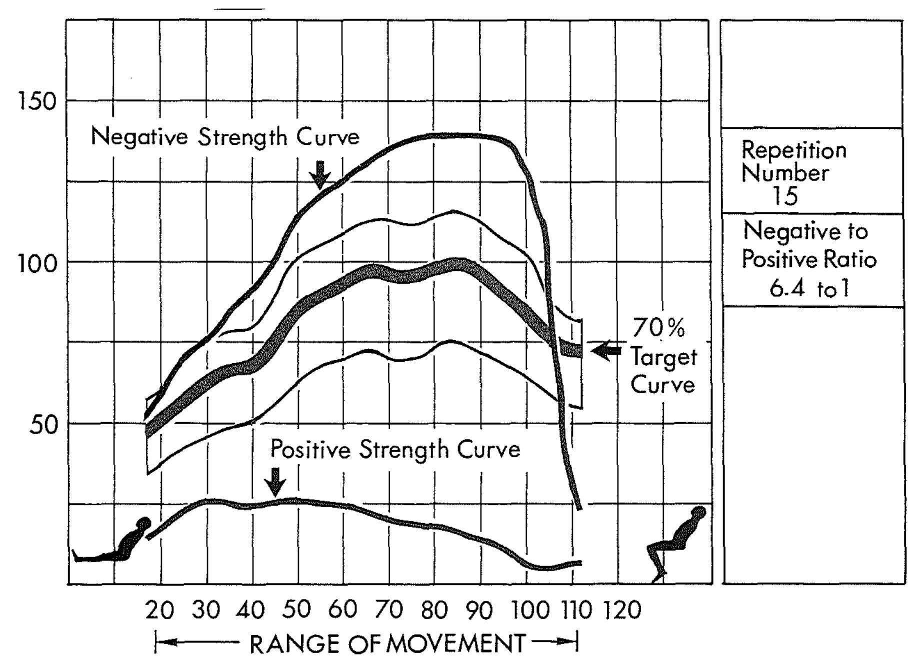
At this point he was doing all he could do, working as hard as possible during both the positive and negative parts of the exercise.

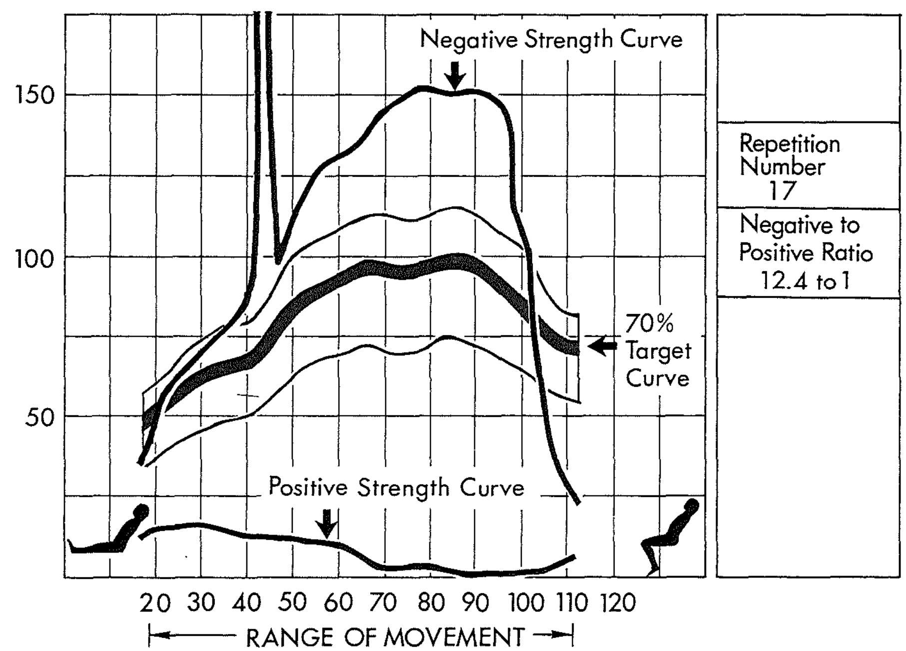
During the 13th repetition his positive work, based upon the area under the curve, was 56 units of work, while his negative work was 146 units of work. Thus, his ratio of negative to positive strength had already changed to 2.7 to 1. Meaning that his negative strength was then 2.7 times as high as his positive strength.

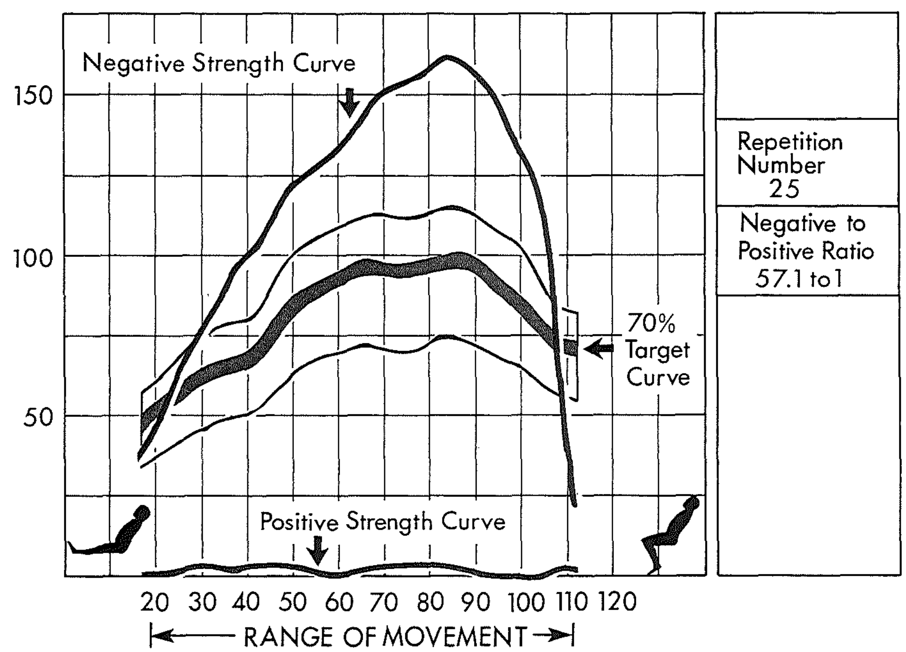
The 15th repetition, shown on the upper right-hand side of the page, shows that his positive strength was dropping, while his negative strength was actually rising. His positive work had declined to 25 units of work, while his negative work had increased to 160 units. And his negative to positive strength ratio was then 6.4 to 1.

The 17th repetition, shown on the bottom left-hand side of the page, shows a continuing drop in positive strength and additional


150
100
50
Negative Strength Curve
Positive Strength Curve
70% Target Curve
Repetition Number 13
Negative to Positive Ratio 2.7 to 1
20 30 40 50 60 70 80 90 100 110 120
RANGE OF MOVEMENT


150
100
50
Negative Strength Curve
Positive Strength Curve
70% Target Curve
Repetition Number 15
Negative to Positive Ratio 6.4 to 1
20 30 40 50 60 70 80 90 100 110 120
RANGE OF MOVEMENT


150
100
50
Negative Strength Curve
Positive Strength Curve
70% Target Curve
Repetition Number 17
Negative to Positive Ratio 12.4 to 1
20 30 40 50 60 70 80 90 100 110 120
RANGE OF MOVEMENT


150
100
50
Negative Strength Curve
Positive Strength Curve
70% Target Curve
Repetition Number 25
Negative to Positive Ratio 57.1 to 1
20 30 40 50 60 70 80 90 100 110 120
RANGE OF MOVEMENT

increases in negative strength. Positive work then being only 13 units, while negative work had increased to 164 units. The negative to positive strength ratio had increased to 12.4 to 1.

The very high and dangerous spike of force running clear off the top of the chart during repetition number 17 was an unavoidable result of any type of isokinetic resistance. Was duplicated in several other repetitions that are not shown.

During the final repetition, number 25, shown on the bottom right-hand side of the page, his positive work had dropped to only 3 units, while his negative work was up to 173 units. The ending negative to positive strength ratio was 57 to 1; meaning that his negative strength was then more than fifty-seven times as high as his positive strength.

Comparing his demonstrated strength and work capacity during the 13th repetition to the same factors during the 25th repetition gives a clear picture of just what occurred inside the muscle as the work continued and the fatigue increased. His positive strength declined in excess of 94 percent, while his negative strength increased by more than 18 percent.

So, then, what was his real strength?

His static strength, the actual strength of the muscle itself, decreased by only 13 percent between the 13th and 25th repetitions. The great changes in both positive and negative strength were largely due to an enormous increase in internal muscular friction.

Because of these changes in both positive and negative strength that are produced by fatigue, largely produced by increasing internal muscular friction, it is meaningless to attempt to determine what happens to strength as a consequence of fatigue by measuring either positive or negative strength.

So my many years of work with isokinetic testing machines finally paid off; in a surprising way, by creating an opportunity for me to learn just what is required for meaningful test results.

CAUTION . . . the type of test outlined above is extremely dangerous and should never be attempted; we perform such tests with a clear awareness of the dangers and only for research purposes.

Since the test outlined above, we have conducted similar tests with several hundred other subjects . . . but never carried these other tests quite that far, for what should be obvious reasons; the results always being the same . . . regardless of level of fatigue, three tests of strength immediately following the exercise always establish a static strength midway between the levels of positive and negative strength.

But most people remain totally unaware of this relationship, even people who badly need this knowledge; people who continue to waste their efforts in attempts to produce meaningful test results from isokinetic machines . . . test results that would be meaningless even if they were accurate, which they never are. Which would be bad enough if that was the end of it, but it isn't; such testing procedures are dangerous, because they expose the subject to very high levels of force.

If such risk was perhaps justified by the need for information that could not be obtained in any other fashion, then it would still be a calculated risk . . . but that is certainly not the case; instead, it is danger to no good purpose.

Throughout this book, every few pages, I have stressed the need for safe testing procedures . . . which simply means test procedures that do not involve high levels of force. Exactly the same thing is true in regard to exercise.

Both strength testing and exercise expose the subjects to some level of force that is above the level encountered during their usual activities . . . but the force should be limited to the lowest possible level consistent with the requirements.

Accurate testing and the most productive form of exercise can now be provided while keeping the levels of force quite low . . . far below the levels of force unavoidably involved in isokinetic testing and exercise.

The cause and effect situation in injuries is very simple; force causes injuries . . . all injuries. When a force is imposed on any part of the body, a force that exceeds the structural integrity of the body, then an injury will be produced. Since the structural integrity of any part of the body is an unknown factor until you have exceeded it, at which point you have produced an injury, it follows that the levels of force imposed during either testing or exercise should be reduced to the lowest possible level. Keep the level of force as low as possible and you will automatically raise the level of safety as high as it can ever be.

Fifteen years of research by highly qualified people and millions of dollars in expenses failed to produce an isokinetic machine that was either safe or accurate, and another hundred years of research will not improve the situation; because the concept of isokinetic resistance is wrong, is limited by laws of physics that cannot be avoided, the results being meaningless tests and dangerous testing procedures. Danger produced by wildly varying levels of force and by impact loads that increase the actual force produced by the muscles by several hundred percent.

Safe, accurate and totally specific testing is now available for the most critical areas in the body, the lumbar, the neck and the knee . . . but such testing or exercise cannot be provided with an isokinetic form of resistance; can be provided in only one way . . . not the best way, quite literally the only way, the way we are doing it now. It took more than forty years of continuing research to even establish the requirements for such safe and accurate testing and exercise, then additional years of research and millions of dollars in expenses to provide these requirements. But the results more than justified all of the efforts and expenses.

If you follow the testing protocols outlined in this book then you will be keeping the levels of force at their lowest possible levels . . . and if you practice the style of exercise outlined in this book you will also be keeping the force within the limits of safety. While providing the most productive form of exercise and the only form of accurate testing.