The Future of Exercise
(1997 and Beyond)

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Requirements for Proper Exercise (con't)

The relatively poor strength increases that were produced in the unworked range of movement during Joe Cirulli's rehabilitation, increases that were poor when compared to those produced in the worked range of movement while he was still performing limited-range exercise, were, nevertheless, strength increases; such strength increases in the unworked range can be attributed to either one or both of two factors; it could be that Joe is a Type G subject, and if so then he will produce at least some strength increases in an unworked range of movement even when performing only limited-range exercise.

But another possible explanation might be the fact that Joe did perform some full-range exercise during that period; we performed several three-part testing procedures during the course of his rehabilitation. These test procedures are called "fatigue response" tests; the subject is first tested for full-range strength, is then exercised full-range until unable to continue movement against the level of resistance being used, and then, immediately after the exercise is finished, the remaining level of full-range strength is measured again.

Most people, given a usual mixture of fiber types in their muscles, will lose about 20 percent of their fresh strength if they fail after ten repetitions of the exercise. But subjects with a high percentage of fast-twitch fibers in their muscles may lose much more of their fresh strength when tested in this fashion, while subjects with a high percentage of slow-twitch fibers may lose very little of their fresh strength when tested in this manner. And a few subjects may lose none of their fresh strength when tested this way, may even be stronger after the exercise than they were before the exercise. Which last point is something that I cannot explain, since it appears to violate common sense, but having seen such responses repeatedly I cannot deny their existence.

Based upon the results of tests conducted with Joe before his injury, we were clearly aware that he has a higher than usual percentage of fast-twitch fibers in his quadriceps muscles; he would usually lose more than 40 percent of his fresh strength as a result of an exercise that was carried to a point of failure after ten repetitions, so his level of resulting fatigue was more than twice as high as usual.

Yet, when he was exercised to failure after ten repetitions at the start of his rehabilitation, he lost only 11 percent of his fresh strength. Then, later, about halfway through his rehabilitation, he lost 25 percent of his fresh strength when tested and exercised in that fashion, and, when fully rehabilitated, he lost 44 percent of his fresh strength when tested and exercised that way. So it appeared that his fiber type was changing as he gained strength; but that was a misleading impression produced by the fact that atrophy is selective in regard to fiber types; fast-twitch fibers atrophy faster and to a greater degree than slow-twitch fibers do. So we were not changing Joe's fiber type make-up, but were, instead, reactivating fast-twitch fibers that had stopped functioning as a result of atrophy, fibers that started functioning again as he became stronger.

Fiber types in muscles are results of genetics, and cannot be changed, but will sometimes appear to change as the level of strength goes up or down; a very weak subject, when first tested, may appear to have a high percentage of slow-twitch fibers, but later, following significant strength increases, they may turn out to have a high percentage of fast-twitch fibers. Such frequently-misleading results are seen rather often in clinical practice.

Differences in muscular fiber types were not even suspected by most people until fairly recently, but have now resulted in a great deal of controversy. Since it would require several hundred pages to cover all of the many theories about muscular fiber types, I will have very little to say on the subject; will, instead, use a few charts showing the results produced by testing the strength of muscles both before and immediately after exercise.

fig. 1

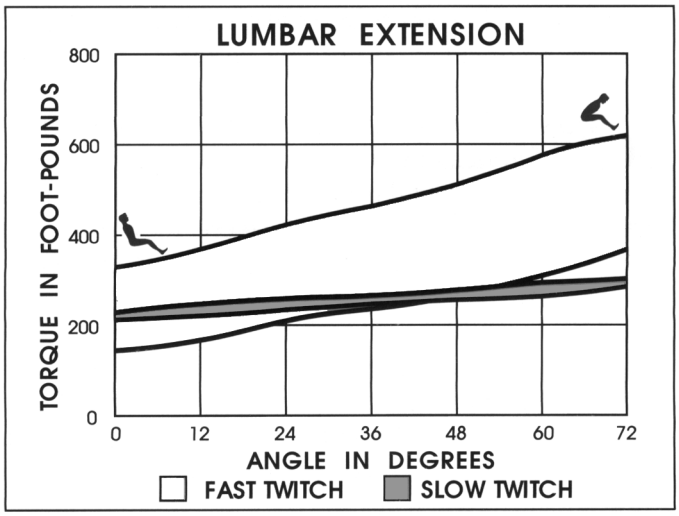


Figure 1: The two strength curves (with white shading between) that are displayed on this chart are the pre-exercise and the post-exercise test results of a subject with an unusually high percentage of fast-twitch muscle fibers in his lumbar-extension muscles.

The highest of the two curves represents the level of fresh strength of the totally isolated muscles that extend the lumbar spine, tested throughout a full range of possible movement. The lowest curve shows the level of strength remaining immediately after an exercise for these muscles.

The differences between these two strength curves are the effects of the exercise, the immediate consequences of the exercise. An average reduction in strength of approximately forty-five percent, with a loss in excess of fifty percent in the extended position.

The exercise that produced this large reduction in the starting level of strength was not a hard exercise in any sense of the word; on the contrary, the resistance was very low for a subject with this demonstrated level of fresh strength, and only six repetitions were performed with this low level of resistance. The exercise was not continued to a point of momentary failure; nevertheless, the loss of strength was very great, which is a typical effect for subjects with a high percentage of fast-twitch fibers in the lumbar muscles.

If the exercise had been continued to a point of momentary exhaustion, then the loss of fresh strength would have been approximately eighty percent.

People with this type of muscle fibers in their lumbar muscles are usually very strong in proportion to their size, but have almost no muscular endurance. Will quickly reach a point of exhaustion as a consequence of even very light work.

The other two curves displayed by this chart (with grey shading between) represent the pre-exercise and post-exercise tests of full-range lumbar-extension strength of a subject with a very high percentage of slow-twitch fibers in these muscles. In this case, the highest of the two curves represents the post-exercise results; the exercise did nothing in the way of reducing his fresh level of strength, actually increased his starting strength. Typical results for a subject with this type of muscle fibers.

This subject was far weaker than the previous subject, less than half as strong in the flexed position and only slightly more than sixty percent as strong in the extended position. Weaker by far, but provided with a genetic advantage of much greater importance than strength; subjects with this type of muscle fiber have an enormous level of work capacity, can continue for hours at a pace of work that would totally exhaust the previous subject in a matter of minutes.

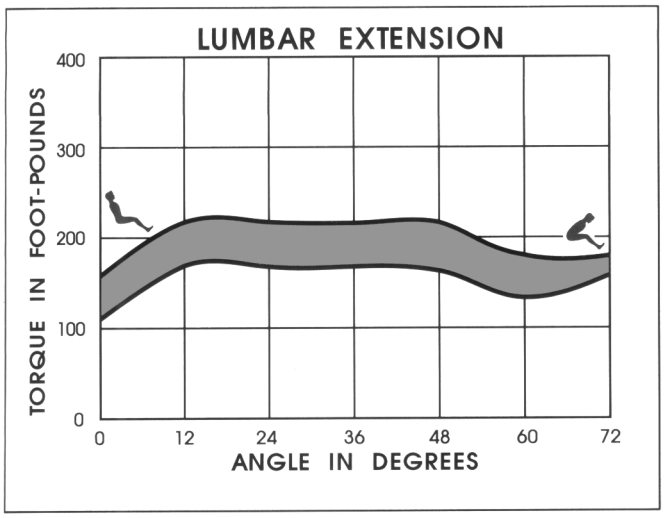
This subject was contrasted with the fast-twitch subject; both subjects were tested before and after an exercise, and both subjects performed the same numbers of repetitions with the same level of resistance, a low level of resistance for the fast-twitch subject but a high level of resistance for the slow-twitch subject.

Six repetitions with low resistance reduced the fast-twitch subject's starting strength approximately 45 percent, while six repetitions with high resistance actually increased the slow-twitch subject's starting strength by more than 8 percent.

We have conducted such side by side tests with these two subjects on several occasions, sometimes terminating the exercise after only a few repetitions and sometimes continuing the exercise to a point of exhaustion. In one such test,

using the same level of resistance for both subjects, a low level of resistance for the much stronger fast-twitch subject but a very high level of resistance for the slow-twitch subject, the fast-twitch subject failed after 23 repetitions with 150 foot-pounds of resistance, could not then produce enough force to continue the movement, after which exercise his starting level of strength was reduced approximately seventy percent. In contrast, the slow-twitch subject continued the exercise for a total of 30 repetitions, moving continuously under load for five minutes and thirty-one seconds without pause or rest; after which exercise his strength was 5.6 percent higher than it was prior to the exercise.

fig. 2



3,450 foot-pounds of mechanical work by his totally isolated lumbar-extension muscles reduced the fast-twitch subject's fresh strength by seventy percent, while 4,500 foot-pounds of isolated work increased the slow-twitch subject's starting strength by more than five percent.

Before the exercise the fast-twitch subject was more than 92 percent stronger than the slow-twitch subject, based upon the areas under the fresh strength curves. More than twice as strong in the flexed position and throughout the first 24 degrees of movement in the direction of extension.

But immediately after the exercise, the slow-twitch subject was more than 7 percent stronger than the fast-twitch subject, based upon the areas under their exhausted strength curves.

While the fast-twitch subject was still somewhat stronger after the exercise in the first two positions where their strength was tested, in the flexed position and twelve degrees away from the flexed position, the slow-twitch subject was the strongest in five of the seven positions that were tested throughout a full range of possible movement.

Figure 2 shows the pre-exercise and post-exercise test results of another subject with an unusually high percentage of slow-twitch muscle fibers in his lumbar-extension muscles. Tested immediately after the exercise this subject was 23 percent stronger than he was prior to the exercise; among thousands of subjects that we have tested, this is one of the most extreme examples of a slow-twitch subject that we have encountered.

But this chart is interesting for several reasons apart from the subject's fiber type; all of the preceding charts have been related to normal subjects, but this chart was produced by a man with a known problem in his lumbar spine.

There are two points of particular interest; one, the abnormal shape of the strength curve . . . and, two, the fact that he duplicated the shape of the abnormal curve in both of the tests.

Such duplication of an abnormal strength-curve in both tests is clear proof of an existing abnormality; but this is a point that I will return to with additional examples somewhat later, so I will not go into any detail on this subject here.

People with an unusually high percentage of either fast-twitch or slow-twitch muscle fibers represent only a small minority of a random group of subjects, but clinical experience with approximately 1,000,000 cases of chronic lower-back pain indicates that fast-twitch subjects are more likely to have lower-back problems than people with different fiber types are.

Secondly, it is now obvious that people with a high percentage of fast-twitch fibers should not be exercised frequently, and will probably lose strength if exercised with high repetitions.

fig. 3

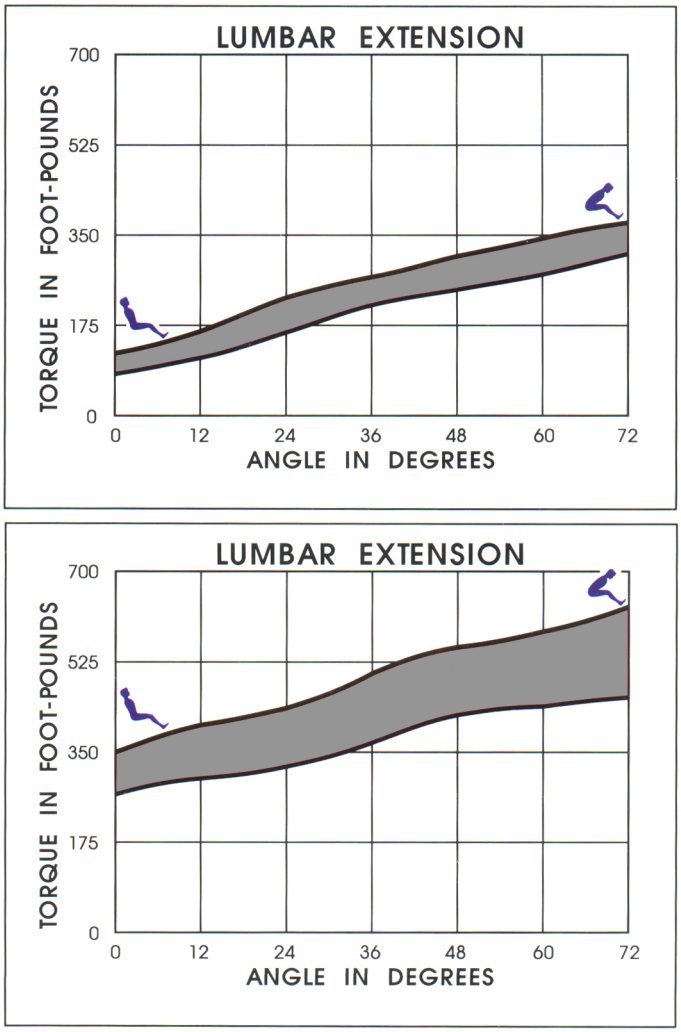


Figure 3 shows the pre-exercise and post-exercise strength test results produced by a male subject on two different occasions, before and after ten weeks of isolated exercise; the top set of curves represent his pre and post-test results at the start, while the lower set of curves show his pre and post-test results ten weeks later.

Note that his exhausted level of strength following the last exercise was far higher than his fresh level of strength prior to the first exercise. Exhausted strength after ten weeks of training being more than twice as high as fresh strength at the start in the fully-extended position.

This subject was Scott Leggett, a member of the research staff at the University of Florida College of Medicine in Gainesville. A man who had performed hard, heavy exercise for several years on a regular basis; exercise that obviously did very little for the strength of his lumbar-extension muscles. Even after several years of heavy exercise his lumbar muscles remained at a level far below their real potential . . . chronic disuse atrophy of these muscles in spite of his previous exercise.

During this period of ten weeks his strength increased much more in the extended position than it did in the flexed position, 180 percent versus 68 percent; which means that his strength curve was becoming much flatter. At the start his ratio of flexed strength to extended strength was 2.95 to 1 . . . ten weeks later his ratio was 1.77 to 1; his extended strength still not being in proper proportion to his flexed strength, but much closer than it was at the start.

Exercising these muscles once a week night not appear to be enough, but our experience indicates that it may well be too much. Several hundred subjects were exercised in this manner in three different locations . . . some once a week, some twice a week, some three times a week, and some only once each two weeks.

When the strength increases that were produced by the various groups were compared, it appeared that the frequency of exercise made little or no difference; all of the groups gained strength, with no significant difference from one group to another. But those results were somewhat misleading, because they were based upon the average strength increases produced by each group. One subject, a very athletic woman who obviously had a very high percentage of fast-twitch fibers in her lumbar muscles, was randomly included in the group that exercised three times each week, which turned out to be a mistake, because she steadily lost strength throughout the twelve weeks of exercise.

If she had been exercised only once a week, or even once every two weeks, then instead of losing strength she would almost certainly have gained strength. But, for her, exercising three times a week was simply too much, she could not tolerate that frequency of exercise. So she suffered the effects of overuse atrophy.

It should also be noted that her fiber type appeared to change; at the start she obviously had a high percentage of fast-twitch fibers, but at the end she appeared to have a usual mixture of fiber types. Evaluating the results of an exercise program by looking only at the average results of a group as a whole is frequently very misleading; nevertheless, that is the way most scientists still judge the results of their research programs. Which is one more in a long list of mistakes that have been made during most of the research performed in attempts to determine the best program of exercise for increasing strength.

Figure 4 shows a progress report on another of our research subjects during a period of five months and eight days; the subject in this case was a man who had performed heavy exercise on a regular basis for nearly twenty years. Now in his mid-thirties he is of average height, weighs 190 pounds and is very muscular.

The curves on this chart represent full-range strength tests of his totally isolated lumbar-extension muscles on five separate occasions, all of the tests being of his fresh, rested strength.

He is a Type S subject, at the start could not reach a full range of normal lumbar extension; on this chart we have continued the curve out to the level of strength that would have existed if he had been capable of reaching full extension.

In the beginning, he could not move closer than 6 degrees from a normal position of full extension; but in all later tests, then being stronger, he was able to reach full extension.

fig. 4

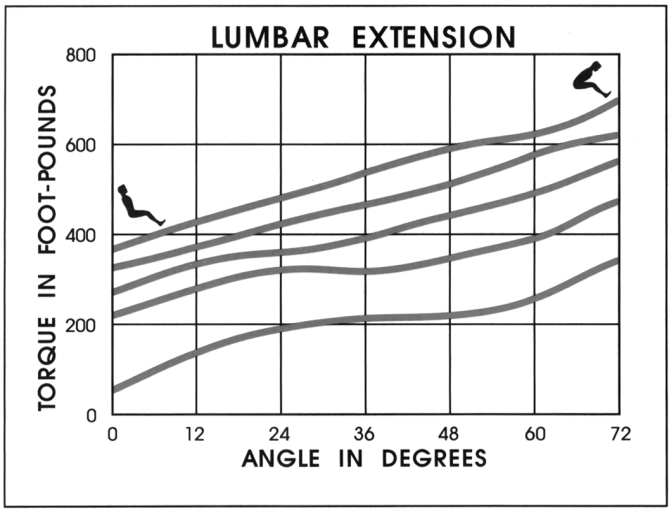
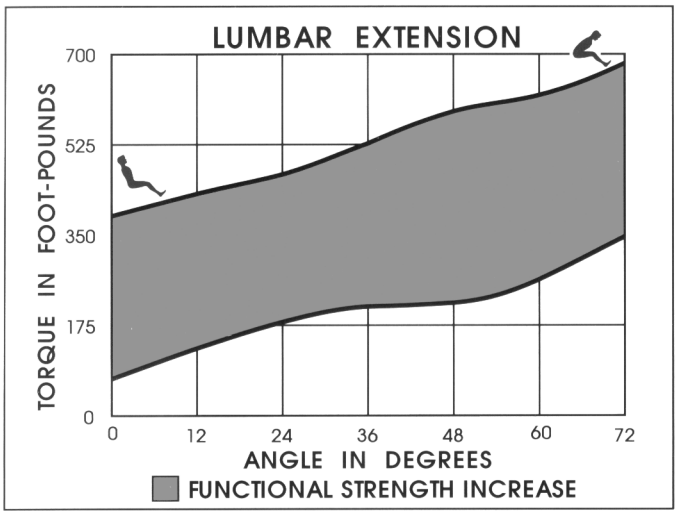


fig. 5



In the flexed position his fresh strength increased more than 100 percent from 340 to 686 foot-pounds. While in the extended position his fresh strength increased by more than 450 percent . . . if we use the continued to extension starting level of strength for comparison purposes.

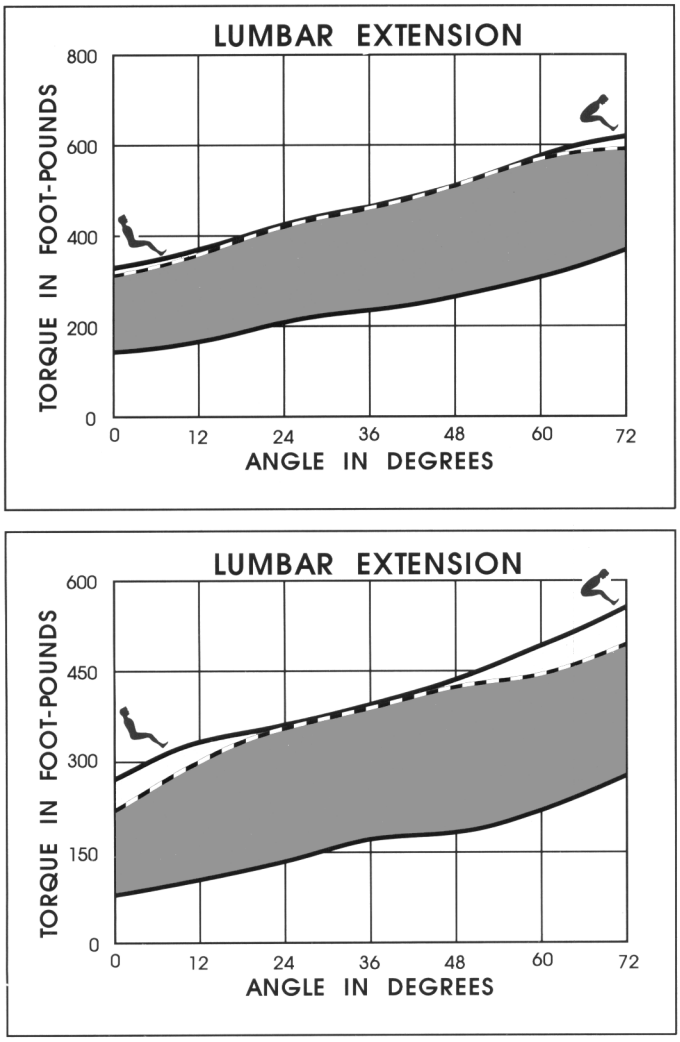
Or, if we use the most extended position that he could reach at the start, compared to the same position in the latest test, then his strength increased by 300 percent.

In either case the magnitude of increase and the rate of increase exceed anything that is possible with a normal muscle . . . so again we have a clear example of chronic disuse atrophy in spite of years of hard exercise.

Figure 5: A report on another Type S subject over a period of seventy-six days. This subject was a male, forty years of age, six feet four inches tall at a muscular weight of 250 pounds; with a history of more than twenty years of hard, regular exercise.

At the start, shown by the lowest of the curves, he could not reach a position of full extension , , , which is typical for Type S subjects; so we have continued the lowest curve by six degrees of movement. In the later tests he could reach full extension.

fig. 6



If we compare the continued to full-extension curve to full extension later, then his extended strength had increased by more than 1,460 percent. But if, instead, we compare his actually most-extended position at the start to the same position at the end, then his strength had increased by 400 percent. And again, in either case, an impossible result with a normal muscle. Chronic disuse atrophy in spite of twenty years of hard exercise.

But there are several points of great interest that are clearly demonstrated by this chart.

During his initial test this subject had a slight dip in his strength curve followed by a flat spot that extended horizontally across the chart for a distance representing approximately thirty-one degrees of movement . . . the flat spot running from about fifty-five degrees to about twenty-four degrees from full extension.

Tested in each of three positions inside that area of movement, his strength varied by only five foot-pounds from the lowest point to the highest point; a variation of less than two percent.

In a second test, approximately six weeks later, represented by the middle curve on this chart, he still retained both the initial dip in strength and the following flat spot; although the flat spot had moved slightly in the direction of extension. In this instance the variation in strength in the range of movement represented by the flat spot was only twelve pounds, a variation of less than three percent.

A little more than a month later, in the third test, represented by the highest of the three curves on the chart, both the dip and the flat spot were still obvious. In this case the variation of strength in the flat spot was less than one percent.

Such dips and flat spots in initial tests of new subjects are common, but usually are quickly corrected as a consequence of specific exercise for the isolated lumbar-extension muscles; as strength increases the curve will generally show a smoothing out of any such irregularities in shape, indicating that weak spots are being brought into proper proportion to the strength in other positions. But this did not occur in this case; which clearly indicates an actual abnormality in lumbar function that may not be correctable by exercise.

Later in the movement, close to full extension, there was a marked downturning in strength following the flat spot in the initial test; but that apparent abnormality corrected itself as a consequence of the exercise and the increasing levels of strength.

This subject had suffered from lower-back pain on an irregular basis over a period of several years; an idiopathic condition apparently related to the lumbar-extension muscles. Pain that has not returned since he started the program of specific exercise for these muscles.

Another subject increased his lumbar strength by an average of more than 31 percent; while his strength in the flexed position increased by 24.2 percent and his strength in the extended position increased by 36.2 percent,

During the same period his dynamic strength increased approximately 35 percent; at the start of this period he failed after 23 repetitions with 150 foot-pounds of resistance . . . later he was able to perform 26 repetitions with 200 foot-pounds of resistance, an increase of thirty-three and a third percent in the level of resistance and an increase of three in the number of repetitions.

He is now exercising with a machine that provides up to twice as much resistance, if and when it is required by the strength of a subject . . . but at that time the machine he was using was limited to a maximum level of resistance of 200 foot-pounds.

His strength level being what it now is, and his fiber type being what it is, fast-twitch fibers in these muscles, he should use a higher level of resistance and a lower number of repetitions; exercised to a point of momentary exhaustion using a relatively low level of resistance in proportion to his existing strength, he may not fully recover from the exercise for a period of two weeks or more.

If exercised again before full recovery has occurred, then the result will be a loss in strength rather than a gain.

The increase in strength was not produced by a man who was starting from scratch; before his strength was first measured, he had already increased his lower-back strength to an almost unbelievable degree by using totally-isolated exercise. Throughout this research program this subject was exercised only once every two weeks.

The top chart in figure 6 shows the results of three full-range strength tests of the same subject; one of the two highest curves is the curve produced by a test of his fresh strength prior to an exercise . . . the lowest curve is a test of his remaining strength immediately after performing only six repetitions with 200 foot-pounds of resistance, an exercise that was not continued to exhaustion . . . the third curve, one of the two higher curves, was a test of his strength performed less than four hours after the exercise, a test performed in order to determine his rate of recovery from the exercise.

Based upon the areas under the curves, the pre-exercise test and the later recovery test showed a difference of less than one-fourth of one percent; the point of greatest difference being less than five percent.

Such accuracy and such repeatability is impossible with any other type of test that we are aware of, can be produced in no other manner. Your fingerprints will not repeat themselves with anything even closely approaching this degree of accuracy. But it is a degree of accuracy and repeatability that is essential for meaningful measurement of lumbar function.

The bottom chart on page 836 shows the results of 3 tests performed by the same subject approximately two weeks earlier than the preceding chart; again showing a pre-exercise test, a post-exercise test, and a recovery test about an hour and a half after the exercise. In one position just past the midrange of movement he was almost fully recovered, the difference in strength being less than one percent. In another position closer to the midrange the difference was less than two percent. But there was still a marked difference on both ends of the movement, clearly indicating that recovery was not complete in those positions.

We have conducted such recovery tests with this subject and with a large number of other subjects and there is a distinct pattern to recovery ability . . . on an individual basis.

If exercised, but not to a point of exhaustion, with a temporary loss of fresh strength of from forty-five to fifty percent as a consequence of the exercise, this subject will recover fully within four hours; but tested again two days later his strength will be down by from three to five percent. Then, two or three days later, it will be back where it was four or five days earlier at the time of the pre-exercise test.

Tested two or three days later it will be higher, the fresh strength then having been increased as a result of the exercise. This cycle requires from six to seven days with this subject, but if he is exercised again prior to full recovery then a loss in fresh strength will be produced rather than an increase.

When exercised to a point of momentary exhaustion, with a resulting loss of seventy percent or more of his fresh strength, then he will not recover fully for at least ten days. His level of recovered strength was tested six hours after his latest exercise carried to exhaustion, twenty-six repetitions with 200 foot-pounds of resistance, and his strength was still down from the fresh level by more than forty percent in some positions; and down to a very marked degree in all positions.

Recovery ability varies to a great degree on an individual basis; one subject tested before and after an exercise and then tested for recovery several hours later showed no slightest trace of recovery, repeated his post-exercise results almost perfectly; then when tested again two days later he still showed no sign of recovery, in a period of more than two full days had not even started to recover.

Which perhaps explains why this subject had exercised on a regular basis for several years with no visible signs of results. He had been exercising three times a week, probably remaining in a constant condition of overtraining. Exercised once a week, or perhaps only once every two weeks, he would probably start to show results.

All of the examples given in this chapter are primarily intended to establish only a few points: ONE, good results can be produced by very brief and infrequent exercise; TWO, too much exercise may produce losses in strength; THREE, the best program of exercise must be determined on an individual basis, with careful consideration being given to the type of fibers in the muscles.