

Effect of resistance training on lumbar extension strength

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ABSTRACT

Development of a new testing machine, which stabilizes the pelvis, allowed us to evaluate the lumbar extensor muscles before and after training. Fifteen healthy subjects (29.1 ± 8 years of age) trained 1 day per week for 10 weeks and 10 healthy subjects (33.7 ± 16 years of age) acted as controls. Training consisted of 6 to 15 repetitions of full range of motion variable resistance lumbar extension exercise to volitional fatigue and periodic maximal isometric contractions taken at seven angles through a full range of motion. Before and after the 10 week training period, subjects completed a maximum isometric strength test at seven angles through a 72° range of motion (0° , 12° , 24° , 36° , 48° , 60° , and 72° of lumbar flexion). The training group significantly improved in lumbar extension strength at all angles ($P \leq 0.01$). The result at 0° (full extension) showed an increase from 180.0 ± 25 Nm to 364.1 ± 43 Nm (+102%) and at 72° (full flexion) from 427.4 ± 44.1 to 607.4 ± 68 (+42%) Nm. Results from the control group showed no change ($P \geq 0.05$). The magnitude of gain shown by the training group reflects the low initial trained state of the lumbar extensor muscles. These data indicate that when the lumbar area is isolated through pelvic stabilization, the isolated lumbar extensor muscles show an abnormally large potential for strength increase.

Low back pain is a major health problem in today's society. It has been estimated that 8 out of 10 people will suffer from low back pain at one time or another in their lives.¹⁷ The cost of medical care and lost job time is estimated to be in

the billions of dollars annually.²¹ The etiology of low back pain has puzzled clinicians and allied health professionals. Many attempts have been made to find common factors that link low back pain to precise etiology, but data are often in disagreement. Insufficient strength in the lumbar musculature appears to be a factor related to the development of low back pain.^{2, 13, 16, 18, 29, 32, 37} Rehabilitation programs often employ strength and resistance training techniques and have been shown to increase low back and hip strength.^{20, 27, 28}

Proper strengthening and rehabilitation of the lumbar muscles requires an accurate and effective machine for training and evaluating lumbar extension strength. Quantification of lumbar extension strength is often complicated by the involvement of the stronger gluteal and hamstring muscles. Mayer and Greenberg²⁶ noted that lumbar-pelvic rhythm (rotation) during lumbar testing contributed to the lumbar extension strength measure. Smidt et al.³⁵ have demonstrated the importance of stabilizing the pelvis and lower extremities to isolate the lumbar muscles during testing. Thus, effective assessment and training of the lumbar muscles requires stabilization of the pelvis to isolate the lumbar extensor muscles and minimize the contribution of the hip and leg muscles. In addition, standardization of the testing and training position, correction for the influence of gravitational forces (body weight) during testing and training, and full range of motion measurement are required for accurate quantification of lumbar extension strength.¹⁵

A new lumbar extension machine (MedX, Ocala, FL) has been recently developed to accurately measure full range of motion lumbar extension strength. The machine was designed to stabilize the pelvis and standardize positioning of the upper body, thus allowing for more precise measurement and training of the smaller and weaker lumbar extensor muscles. The purpose of this investigation was to use this new technology to determine the effect of variable resistance training on lumbar extension strength.

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METHODS

Subjects

Twenty-five healthy volunteers, 18 men (age, 32.6 ± 11.4 years; height, 182.0 ± 7.7 cm; weight, 87.4 ± 16.0 kg) and 7 women (age, 21.8 ± 1.0 years; height, 164.9 ± 4.7 cm; weight, 57.4 ± 5.9 kg) volunteered for this investigation. Fifteen of these subjects were assigned to an exercise training group and 10 acted as controls and did not train. Characteristics of subjects by groups are shown in Table 1. All subjects had been participating in a regular exercise program for at least 1 year. These programs included both aerobic endurance and strength training activities.

The experimental design and protocol was approved of by the institutional review board of the University of Florida College of Medicine, Gainesville, Florida. Written informed consent was obtained from all subjects.

Testing

Before training and after a 10 week training period, each subject completed an isometric strength test on a MedX lumbar extension machine. Each test included measurement of maximal voluntary isometric strength of the lumbar extensor muscles at 0° , 12° , 24° , 36° , 48° , 60° , and 72° of lumbar flexion. Previous research with this equipment^{10,24} has shown the reliability for repeated measurements of lumbar extension strength at multiple joint angles to be high ($r = 0.81$ to 0.97).

Subjects were instructed not to exercise for at least 24 hours before testing. Upon reporting to the laboratory for testing, subjects were seated in the MedX lumbar extension machine with their knees positioned so that the femurs were parallel to the seat (Fig. 1). Subjects were then secured in place by specially designed femur and thigh restraints used to stabilize the pelvis. The femur restraint consisted of two pads that were mounted on an adjustable crank and placed against the anterior side of the tibia at the level of the tibial tuberosity. The thigh restraint consisted of a lap belt that was secured in place over the top of the femurs, just below the waist. Tightening of the femur restraint forced the femurs upwards and to the rear, forcing the pelvis back against a specially designed pelvic restraint (Fig. 1). The thigh restraint was tightened to prevent any vertical movement of the pelvis. The combination of these restraining forces stabilized the pelvis, allowing no lateral, vertical, or rotational movement. A head rest was adjusted to the level of the occipital bone for comfort and support. Standardized

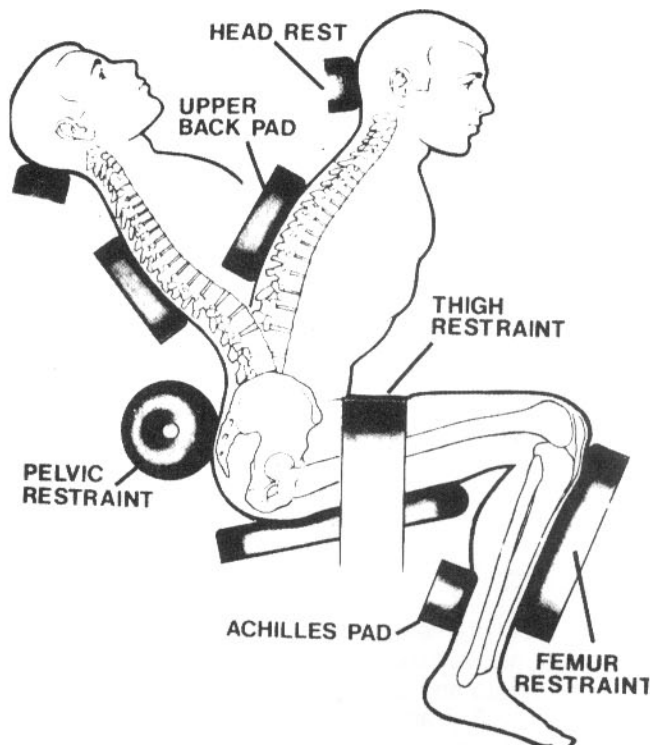


Figure 1. The figure shows the various restraints and pads used for pelvic stabilization and positional standardization during lumbar extension strength testing (MedX).

positioning of the arms was achieved by two handle bars attached to and extending 43 cm from the back pad (movement arm of machine). Subjects were instructed to maintain a light grasp on the handles during the positioning and testing procedures.

After the pelvis was stabilized and the testing position standardized, subjects were moved into a neutral, upright posture (18° to 36° of flexion) and the center line of their torso mass (torso, head, and arms) was established. A counterweight was locked into place at this position and the subject was then moved to 0° of lumbar flexion. The counterweight was adjusted while the subject rested against the back pad at 0° of lumbar flexion to neutralize the gravitational force of the head, torso, and upper extremities. The positions of the torso center line and counterbalance adjustments were recorded and used for all subsequent testing and training sessions.

To initiate a test, subjects were locked into 72° of flexion and instructed to slowly and continuously extend their back against the upper back pad for a 2 to 3 second period. Once maximal tension had been achieved, subjects were instructed to maintain the contraction for an additional 1 to 2 seconds before relaxing. A 10 second rest interval was provided between each isometric contraction while the next angle of measurement was set. During the contractions, concurrent visual feedback was provided on a video display screen interfaced with the machine and subjects were verbally

TABLE 1
Characteristics of the subjects^a

Variable	Control	Training
Men (N)	5	13
Women (N)	5	2
Age (year)	33.7 ± 16.5	29.1 ± 8.2
Height (cm)	176.2 ± 12.0	179.5 ± 9.7
Weight (kg)	76.5 ± 17.4	83.1 ± 20.0

^a Values are means \pm SD.

encouraged to give a maximum effort. To ensure pelvic stabilization, thigh and femur restraints were tightened if pelvic movement was observed during testing. This was easily checked by the notation of any rotation of the pelvic restraint.

Training

Fifteen subjects trained 1 day per week for 10 weeks and 10 served as controls and did not train the lumbar extensor muscles. A conservative training frequency was chosen because of the isolation of the lumbar extensor muscles and the potential for overtraining.

Upon reporting to the laboratory for each training session, subjects were seated in the lumbar extension machine as described previously. Positions of the torso center line and counter balance adjustments were set according to previous testing. For each training session, subjects were required to perform one set of full range of motion variable resistance lumbar extension exercise with a weight load that allowed 6 to 15 repetitions to volitional fatigue (maximal effort). Progressive resistance exercise was achieved by increasing the weight by 10% when 15 or more repetitions could be achieved. The first lumbar extension machine used for training contained a maximum weight stack that required 271.2 Nm of torque to lift. For a 2 week period during the training, most subjects could exceed this weight requirement. During this time the subjects were instructed to limit their repetitions to 15 while slowing the movement during each contraction. A new lumbar extension machine with a maximum weight stack that required 542 Nm of torque to lift was then used for training. At this point, all subjects were given a 10% increase in resistance when they could achieve 12 or more repetitions. Every 1 to 3 weeks, subjects repeated the maximal isometric test as described above, as well as completed the full range of motion variable resistance training. Subjects were retested after the 10 weeks of training on the same machine on which they were tested initially.

Data analysis

Isometric strength was measured in units of torque (Nm). Means and standard deviations were calculated for each angle of measurement. Between group comparisons were made using analysis of variance (ANOVA). Changes in strength within groups were analyzed using ANOVA for repeated measures. Changes in weight used in variable resistance (Week 1 versus Week 10) training were analyzed using a paired *t*-test. ANOVAs and paired *t*-tests were performed using the SAS³⁴ general linear models and means procedures. A *P* value of ≤ 0.05 was required for statistical significance.

RESULTS

The training group was not significantly different from the control group with respect to age, height, and weight ($P \geq$

0.5) (Table 1). The training group was not significantly different from the control group in initial isometric strength at any of the angles measured ($P \geq 0.05$) (Table 2). The training group significantly improved isometric lumbar extension strength at all angles ($P \leq 0.01$), whereas the control group did not change ($P \geq 0.05$). The training group significantly improved in the amount of variable resistance weight lifted to fatigue from Week 1 to Week 10 ($P \leq 0.01$) (Table 2). Absolute values in strength and the SEM before and after the 10 week training period for both groups are illustrated in Figure 2. A nonsignificant time-by-angle interaction for the training group indicated that the shape of the curve did not change with training. The strength curve shown in Figure 2 illustrates that the lumbar extensor muscles are weaker in the more extended position compared to strength in the flexed range of motion, which is in agreement with our population data base.^{10, 24}

DISCUSSION

The unique finding of this study was the magnitude of full range of motion training responses of the isolated lumbar extensor muscles. This increase in lumbar extension strength was particularly evident in the more extended positions. The isometric strength gain in the lumbar extensor muscles in this study was greater than what has been reported in the literature for other muscle groups. Subjects in the present investigation showed gains in isometric strength ranging from 102% (0° flexion) to 42% (72° flexion). Smith and Melton³⁶ reported a 14.6% increase in quadriceps strength for an isotonic variable resistance group when evaluated using an isometric test. Graves et al.¹¹ were able to show increases in peak isometric leg extension strength of 22.1% for those who trained 18 weeks and 19.5% for those who trained 10 weeks. O'Shea³³ found 19.9% improvement in deep knee bend isometric strength after 6 weeks of training 3 days per week. A review of seven other training studies reported by Fleck and Kraemer⁶ showed an average increase in isometric strength of 29.8% with isometric training.

The magnitude of improvement found in strength training programs with dynamic training is similar to that which has been reported for isometric training. In a review by Fleck and Kraemer,⁶ 13 studies representing various forms of isotonic, variable resistance, or isokinetic training using the bench press, showed an average improvement in strength of 23.3% when tested on the equipment with which the subjects were trained, and 16.5% (6 studies) when tested on special isotonic or isokinetic ergometers. Fleck and Kraemer⁶ also reported an average increase in leg press strength of 26.6% when subjects were tested with equipment on which they had trained (six studies) and 21.2% when tested with special isotonic or isokinetic ergometers (five studies).

Two studies have been conducted on healthy young subjects who were trained and tested for low back strength. Flint⁷ trained 27 females, ages 18 to 35 years, two times per week for 12 weeks. Training consisted of 10 repetitions of back extensions conducted on a specially designed table with

TABLE 2
Pretraining and posttraining isometric (Nm) and dynamic (kg) strength values^a

Test condition (group)	Isometric Strength Angles of lumbar flexion (deg)							Dynamic training weight ^b	Reps
	0	12	24	36	48	60	72		
Pretest (Control)	206.7 ± 30.8	255.2 ± 34.9	272.0 ± 33.5	292.4 ± 39.2	303.6 ± 42.6	328.7 ± 45.4	355.4 ± 48.9		
Posttest (Control)	186.7 ± 24.1	232.6 ± 27.3	260.9 ± 28.5	284.5 ± 30.8	306.3 ± 38.8	317.3 ± 38.6	361.2 ± 40.1		
Pretest (Training)	180.0 ± 24.5	235.0 ± 34.8	292.1 ± 35.9	304.0 ± 35.8	336.1 ± 39.1	371.6 ± 37.6	427.4 ± 44.1	68.4 ± 22.0	11.4 ± 1.3
Posttest (Training)	364.1 ^c ± 42.9	407.6 ^c ± 47.2	443.1 ^c ± 47.7	484.3 ^c ± 50.7	519.8 ^c ± 56.1	562.6 ^c ± 63.4	607.4 ^c ± 67.9	110.2 ^c ± 46.9	11.7 ± 1.2

^a Values are means ± SEM.

^b Values represent variable resistance training weight used at T₁ and T₂.

^c P ≤ 0.01 compared with pretraining strength.

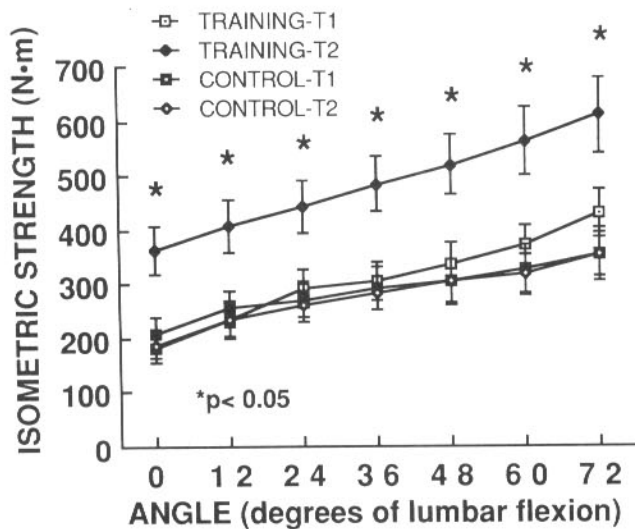


Figure 2. Torque (Nm) measurements for isometric strength of the lumbar extensor muscles at 0°, 12°, 24°, 36°, 48°, 60°, and 72° of lumbar flexion. T₁ and T₂ show before and after 10 week training measurements, respectively. Data represent means and ±SEM.

subjects in the prone position. The table was elevated in the middle at a 90° angle. The subjects wore a "vest-harness" which was attached to pulley weights by a rope that was passed through a hole in the table top. Her subjects showed a 27.8% increase in isometric back strength. Berger¹ trained 37 men statically and 37 dynamically, 3 times per week for 12 weeks. Static training was conducted in the seated position with the subject pulling back on a rod attached to a dynamometer. Dynamic training was conducted on a table that allowed the subject's trunk to be raised from the vertical to the horizontal position. To add resistance, a weight or barbell was placed behind the neck. The isometrically trained group improved 14.8% with isometric testing and 17.6% with dynamic testing. The isotonicly trained group improved 7.1% with isometric testing and 21.6% with dynamic testing. Thus, the amount of strength gain found in resistance training experiments conducted on healthy, sedentary subjects for both isotonic or isometric training aver-

ages from 20% to 30%. This magnitude of improvement was also found in the two studies in which subjects were trained with back extension exercise.

It has been demonstrated that participants who are untrained or who have a low strength level with respect to their strength potential have a greater capacity to acquire strength than those who are highly trained or who are already close to their maximal strength potential.^{12,14} deVries³ and Fleck and Kraemer,⁶ in recent reviews of exercise prescriptions for resistance training, alluded to the importance of this concept when evaluating the effectiveness of resistance training programs. Normally, it is expected that moderate to highly trained individuals will show little to no further change in strength with additional training. Subjects in the present investigation were well-trained and had been participating in exercise programs for a minimum of 1 year. Most importantly, 10 of the 15 subjects in the training group had been exercising on the Nautilus low back machine (Nautilus Sports Medical Industries, Inc., Dallas, TX) on a regular basis. Thus, if the low back extensor muscles were being adequately trained in these subjects initially, significant gains in strength would not have been expected.

The results of this study, however, showed unusually large increases in isometric lumbar extension strength, particularly in the more extended positions. Dynamic training weights also increased to a great extent (60.6%). How can these large gains in lumbar extension strength be explained? The most reasonable explanation is that lumbar extensor muscle strength is not normally developed or maintained with existing exercise methods. As mentioned in the introduction, without proper stabilization of the pelvis, the larger and stronger thigh (mainly hamstring) and gluteal muscles do most of the exercise in back extension.^{10,15,35} This situation may be equivalent to that of a muscle that has been placed in a cast; it is in a state of chronic disuse, atrophies quickly, and loses its size and strength.^{4,5,23,25,31,38} Thus, the lumbar extensor muscles never develop to their fullest potential and become atrophied from chronic disuse. This explains why the isolated lumbar extensor muscles have so much potential for strength development.

The results from this investigation emphasize the importance of full range of motion testing and training. For

example, the studies of Berger¹ and Flint⁷ evaluated and trained subjects at one point of the range of motion. It is well established that in most individuals, when a muscle is trained at a given angle, its strength increases from 15° to 20° either side of that point.^{8, 9, 19, 22} Thus, an angle-specific training response has been identified for isometric exercise. The fact that lumbar extensor muscle strength varies so greatly through the full range of motion^{10, 24} makes single point or limited range testing or training inadequate.^{10, 15, 24, 35}

Whether the magnitude of strength gain found in this study is attributable to hypertrophy related to specific biochemical and histochemical adaptations to training or neural factors is beyond the scope of this study. Moritani and deVries³⁰ have attributed strength increases during the first 3 to 5 weeks of resistance training to neuromuscular factors. They believe that muscle hypertrophy becomes the predominant factor in strength increases after this period of time. Because the lumbar extensor muscles seem to exist in a state of chronic disuse under normal conditions, increases in strength are most likely partially attributable to neural factors.

If the neural adaptations to training are easily acquired, the possibility of strength increases from the isometric testing alone must be considered. Previous research on the MedX lumbar extension machine^{10, 24} showed that after 2 days of testing, strength increases attributable to learning had leveled off. Subjects were tested on four occasions 3 to 7 days apart. The purpose of the study was to test the reliability and variability of the MedX lumbar extension machine. The results showed an 8% to 10% (flexion to extension, full range of motion isometric testing) increase in lumbar extension strength from Day 1 to Day 2, but no difference from Day 2 to Day 3 or 4. Thus, the magnitude of increase in lumbar extension strength in this study could not be attributed to a learning factor associated with isometric testing. The fact that the control group did not significantly ($P \geq 0.05$) increase lumbar extension strength supports this fact. Therefore, if part of the increase in strength from this study were attributable to neural adaptations, the adaptations were a result of an exercise training response and not a learning effect associated with the testing procedure.

In summary, the data presented here have important practical applications for individuals participating in resistance training programs for the low back. Exercising 1 day per week with isolated lumbar extension exercise can substantially increase the strength of the lumbar extensor muscles after 10 weeks of training. To properly train the lumbar extensor muscles, isolation of the lumbar area to eliminate the contribution of forces from other muscle groups is required. The magnitude of strength gain shown in this study reflects the poor initial trained state of the lumbar extensor muscles. Further research is necessary to determine the optimal frequency and/or duration of training necessary to produce the greatest improvement in lumbar extension strength.

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REFERENCES

- Berger RA: Comparison of static and dynamic strength increases. *Res Q* 33: 329-333, 1962
- Chaffin DB, Herrin GD, Keyserling WM: Preemployment strength testing. *JOM* 67: 403-308, 1978
- deVries HA: *Physiology of Exercise for Physical Education and Athletics*. Fourth edition. Dubuque, WC Brown Publishers, 1986, pp 396-400
- Edstrom L: Selective atrophy of red muscle fibers in the quadriceps in long-standing knee joint dysfunction. Injuries to the anterior cruciate ligament. *J Neurol Sci* 11: 551-558, 1970
- Edwards RHT, Jones DA: Diseases of skeletal muscle. In Peachey LD (ed): *Handbook of Physiology*, section 10: Skeletal Muscle. Bethesda, Maryland, American Physiological Society, 1983, pp 633-672
- Fleck SJ, Kraemer WJ: *Designed Resistance Training Programs*. Champaign IL, Human Kinetics Books, 1987, pp 16-23
- Flint MM: Effect of increasing back and abdominal muscle strength and low back pain. *Res Q* 29: 160-171, 1958
- Gardner GW: Specificity of strength changes of the exercised and nonexercised limb following isometric training. *Res Q* 34: 98-101, 1963
- Graves JE, Pollock ML, Jones AE, et al: Specificity of limited range of motion variable resistance training. *Med Sci Sports Exerc* 21: 84-89, 1989
- Graves JE, Pollock ML, Carpenter DM, et al: Quantitative assessment of full range-of-motion isometric lumbar extension strength. *Spine*, in press, 1989
- Graves JE, Pollock ML, Leggett SH, et al: Effect of reduced training frequency on muscular strength. *Int J Sports Med* 9: 316-319, 1988
- Hakkinen K: Factors influencing trainability of muscular strength during short term and prolonged training. *Natl Strength Condit Assoc J* 7: 32-34, 1985
- Hasue M, Masatoshi F, Kikuch S: A new method of quantitative measurement of abdominal and back muscle strength. *Spine* 5: 143-148, 1980
- Hettinger T: *Physiology of Strength*. Springfield, IL, Charles C Thomas, 1961, pp 57-60
- Jones A, Pollock M, Graves J, et al: *The Lumbar Spine*. Santa Barbara, Sequoia Communications, 1988
- Kanon E, Goldfuss AJ: In-plant evaluation of the muscle strength of workers. *Am Ind Hygiene Assoc* 39: 801-807, 1978
- Kelsey JL, White AA, Pastides H, et al: The impact of musculoskeletal disorders on the population of the United States. *J Bone Joint Surg* 61A: 959-964, 1979
- Keyserling WM, Herin GD, Chaffin DB: Isometric strength testing as a means of controlling medical incidents on strenuous jobs. *JOM* 22: 332-336, 1980
- Knapik JJ, Maudsley RH, Rammos NV: Angular specificity and test mode specificity of isometric and isokinetic strength training. *J Orthop Sports Phys Ther* 5: 58-65, 1983
- Kraus H, Nagler W: Evaluation of an exercise program for back pain. *Am Family Phys* 28: 153-158, 1983
- Langrana NA, Lee CK, Alexander H, et al: Quantitative assessment of back strength using isokinetic testing. *Spine* 9: 287-290, 1984
- Lindh M: Increase in muscle strength from isometric quadriceps exercises at different knee angles. *Scand J Med* 11: 33-36, 1979
- Lindboe CF, Platou CS: Disuse atrophy of human skeletal muscle. *Acta Neuropathol* 56: 241-244, 1982
- Leggett SH, Pollock ML, Graves JE, et al: Quantitative assessment of full range of motion lumbar extension strength. *Med Sci Sports Exerc* 20: S87, 1988
- MacDougall JD, Elder GCB, Sale DG, et al: Effects of strength training and immobilization on human muscle fibers. *Eur J Appl Physiol* 43: 25-34, 1980
- Mayer L, Greenberg B: Measurement of the strength of trunk muscles. *J Bone Joint Surg* 4: 842-856, 1942
- Mayer T, Gatchel R, Kishino N, et al: Objective assessment of spine function following industrial injury. A prospective study with comparison group and one-year follow-up. *Spine* 10: 482-493, 1985
- Mayer TG, Gatchel RJ, Mayer H, et al: A prospective two-year study of functional restoration in industrial low back injury. *JAMA* 258: 1763-1767, 1987
- Mayer TG, Smith SS, Keeley J, et al: Quantification of lumbar function Part 2: Sagittal plane trunk strength in chronic low back patients. *Spine* 10: 765-772, 1985
- Moritani T, deVries HA: Neural factors versus hypertrophy in the time course of muscle strength gain. *Am J Phys Med* 58: 115-130, 1979
- Musacchia XJ, Steffen JM, Fell RD: Disuse atrophy of skeletal muscle, animal models. In Pandolf KB: *Exercise and Sport Sciences Reviews*. New York, MacMillan Publishing Co., 1988, pp 61-87
- Nordgren B, Scheile R, Linroth K: Evaluation and prediction of back pain during military field service. *Scand J Rehabil* 12: 1-7, 1980

33. O'Shea P: Effect of selected weight training programs on the development of strength and muscle hypertrophy. *Res Q* 37: 95-102, 1966
34. *SAS Users Guide: Statistics, Version 5 Edition*, Cary, N.C., SAS Institute, Inc, 1985, pp 433-506
35. Smidt G, Herring T, Amundsen L, et al: Assessment of abdominal and back extensor function: A quantitative approach and results for chronic low-back patients. *Spine* 8: 211-219, 1983
36. Smith MJ, Melton P: Isokinetic versus isotonic variable-resistance training. *Am J Sports Med* 9: 275-279, 1981
37. Snook S, Campanelli RA, Hart JW: A study of three preventive approaches to low back injury. *JOM* 20: 478-481, 1978
38. Tomanek RJ, Cooper RR: Ultrastructural changes in tenotomized fast- and slow-twitch muscle fibers. *J Anat* 113: 409-424, 1972