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# Limited Range-of-Motion Lumbar Extension Strength Training

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## Abstract

The purpose of this study was to evaluate the effect of limited range-of-motion (ROM) resistance training on the development of lumbar extension strength through a 72 degree ROM. 33 men and 25 women (age = 30 ± 11 years) were randomly assigned to one of three training groups or a control group (C; $n = 10$) that did not train. Training was conducted once per week for 12 weeks and consisted of one set of 8 - 12 repetitions of variable resistance lumbar extensions until volitional fatigue. Group A ($n = 18$) trained from 72 to 36 degrees of lumbar flexion; group B ($n = 14$) from 36 to 0 degrees of lumbar flexion; and group AB ($n = 16$) from 72 to 0 degrees of lumbar flexion. Prior to and After training, isometric lumbar extension torque was assessed at 72, 60, 48, 36, 24, 12, and 0 degrees of lumbar flexion. Analysis of covariance showed that groups A, B, and AB increased lumbar extension torque ($P \leq 0.05$) at all angles measured when compared with C. The greatest gains in torque were noted for groups A and B in their respective ranges of training but A and B did not differ from AB ($P \leq 0.05$) at any angle. These data indicate that limited ROM lumbar extension training through a 36 degree ROM is effective for developing strength through 72 degrees of lumbar extension. (Key words: lumbar strength curve, isometric strength, isometric testing, variable resistance training)

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# Limited range-of-motion lumbar extension strength training

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**ABSTRACT**

GRAVES, J. E., M. L. POLLOCK, S. H. LEGGETT, D. M. CARPENTER, C. K. FIX, and M. N. FULTON. Limited range-of-motion lumbar extension strength training. *Med. Sci. Sports Exerc.*, Vol. 24, No. 1, pp. 128–133, 1992. The purpose of this study was to evaluate the effect of limited range-of-motion (ROM) resistance training on the development of lumbar extension strength through a 72° ROM. Thirty-three men and 25 women (age = 30 ± 11 yr) were randomly assigned to one of three training groups or a control group (C; $n$ = 10) that did not train. Training was conducted once per week for 12 wk and consisted of one set of 8–12 repetitions of variable resistance lumbar extensions until volitional fatigue. Group A ($n$ = 18) trained from 72° to 36° of lumbar flexion; group B ($n$ = 14) from 36° to 0° of lumbar flexion; and group AB ($n$ = 16) from 72° to 0° of lumbar flexion. Prior to and after training, isometric lumbar extension torque was assessed at 72°, 60°, 48°, 36°, 24°, 12°, and 0° of lumbar flexion. Analysis of covariance showed that groups A, B, and AB increased lumbar extension torque ($P \le 0.05$) at all angles measured when compared with C. The greatest gains in torque were noted for groups A and B in their respective ranges of training but A and B did not differ from AB ($P > 0.05$) at any angle. These data indicate that limited ROM lumbar extension training through a 36° ROM is effective for developing strength through 72° of lumbar extension.

LUMBAR STRENGTH CURVE, ISOMETRIC STRENGTH, ISOMETRIC TESTING, VARIABLE RESISTANCE TRAINING

Low back pain (LBP) is one of the most common and costly medical problems in today's industrialized society (2,7). Because a low level of trunk muscle strength is considered a primary risk factor for low back injury and subsequent LBP (1,2,14), progressive resistance exercise is often prescribed for LBP patients. Pain, joint stiffness, and muscle weakness often limit the range-of-motion (ROM) of LBP patients (13). Back rehabilitation programs that employ progressive resistance exercise usually begin their limited ROM patients with limited ROM exercise that is progressed to a greater ROM as the condition allows.

Studies using isometric exercise as a model to study the development of muscular strength indicate that isometric strength gain is specific to the joint angle at which training takes place (8,15). Previous research on the knee extensor muscles has also shown that when dynamic resistance training is performed through a restricted ROM, strength gains in the untrained ROM are limited (6). Full ROM dynamic resistance exercise is required to maximize strength gains throughout the ROM (6). Thus, a ROM specificity has been established for dynamic as well as isometric exercise training.

There are little data available in the literature describing limited ROM dynamic resistance training on muscle groups other than the knee extensors. Recent advances in machine design involving pelvic stabilization have enabled specific testing (4) and effective training (5,10) for the lumbar extensor muscles. Because of the importance of progressive resistance exercise training in the clinical treatment and prevention of LBP and the fact that many LBP patients have a limited range of lumbar motion, there is a need to evaluate the influence of limited ROM exercise training on the development of lumbar extension strength through a full ROM. The purpose of the present study was to evaluate the influence of variable resistance lumbar extension strength training through a 36° ROM on the development of lumbar extension strength through 72° of lumbar motion.

## METHODS

**Subjects.** Because LBP patients are often limited in their range of lumbar motion (13), asymptomatic subjects were chosen as an experimental model to test the hypothesis that limited ROM lumbar extension training would produce limited ROM strength benefit. This allowed us to maximize the range of lumbar motion investigated. Thirty-three men (age = 31 ± 12 yr; height = 178.3 ± 6.8 cm; weight = 80.9 ± 14.9 kg) and 25 women (age = 29 ± 10 yr; height = 164.1 ± 6.1 cm; weight = 57.5 ± 8.9 kg) volunteered to participate in the study. These subjects were sedentary individuals who had no history of chronic LBP and no cardiovascular or orthopedic contraindications to exercise testing or training. The study was approved by the Institutional Review Board of the University of Florida College of Medicine, Gainesville, Florida. Documented informed consent was obtained from each subject prior to acceptance into the study.

**Pretraining strength testing.** Because dynamic strength tests are limited to specific joint angles, a multiposition isometric strength test was employed to quantify strength through a full ROM. Prior to training all subjects completed three isometric lumbar extension strength tests administered on different days. The test days were separated by at least 72 h to allow the subjects ample time to recover from any residual fatigue or soreness that might have been associated with the tests. The first test was considered a practice session, in accordance with previous research that has shown it is important to familiarize the subjects with the lumbar extension testing procedure to obtain the most reliable results (4). The second and third tests were used to obtain criterion measures of isometric lumbar extension strength.

For each test, isometric lumbar extension torque was assessed at seven positions through a 72° arc of lumbar motion with a MedX™ (Ocala, FL) lumbar extension machine. Previous research has shown that a 72° ROM is normal for lumbar extension when the pelvis is stabilized to minimize pelvic rotation (4,13). The seven positions measured were 72°, 60°, 48°, 36°, 24°, 12°, and 0° of lumbar flexion. Because the torque by angle relationship (strength curve) obtained from multiple joint angle testing can be influenced by fatigue associated with performing repeated isometric contractions (6), the joint angles measured for the criterion tests were set in two different orders. For order 1, the joint angles were set beginning at 72° of lumbar flexion and progressed to 0° of lumbar flexion. For order 2, the joint angles were set in the opposite order, beginning at 0° of lumbar flexion and progressed to 72° of lumbar flexion. The two orders of testing were randomly assigned.The subjects were seated in the lumbar extension machine in an upright position (Fig. 1) and their knees were positioned so that the thighs were parallel to the seat. A restraining belt located over the anterior portion of the upper thigh and femur restraint pads located over the anterior thigh just superior to the knees were secured to prevent any vertical movement of the thighs or pelvis. A force was exerted longitudinally along the legs by cranking the footrest forward. This force pushed the pelvis back against a specially designed lumbar pad (pelvic restraint). In this manner the lower extremities were used to anchor the pelvis against the pelvic restraint to prevent pelvic rotation. To ensure pelvic stabilization, the restraint belt and footrest were tight-

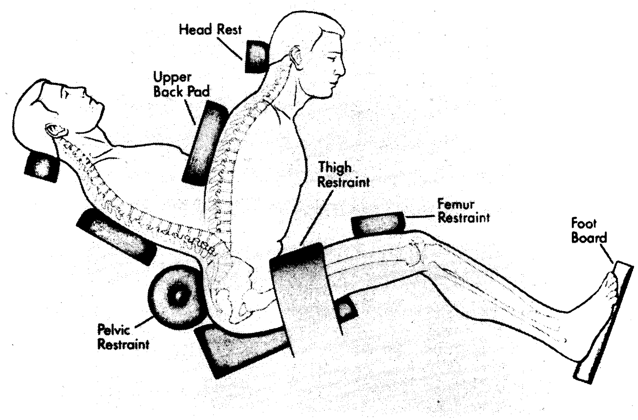


**Figure 1—The restraint system used to isolate the lumbar extensor muscles through pelvic stabilization.**

ened if pelvic movement was observed during the test. This was easily checked by noticing any rotation of the pelvic restraint. A headrest was adjusted to the level of the occipital bone for comfort, support, and positional standardization. Standardized positioning of the arms was achieved by two handlebars attached to and extending 43 cm from the movement arm. 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, the subjects were moved into an upright posture between 18° and 36° of lumbar flexion, where the influence of gravity on their torso mass (torso, head, and arms) was neutral. A counterweight was then locked in place at this neutral, upright position. The counterweight was then adjusted while the subject rested against the upper back pad (attached to the movement arm of the machine) at 0° of lumbar flexion to counterbalance the gravitational force on the head, torso, and upper extremities. Subjects were then checked for any limitations in their range of lumbar motion.

To begin each test, the movement arm of the machine was locked into place and the subjects were instructed to extend back against the upper back pad by gradually building tension over a 2–3 s period. Once maximal tension had been achieved, the subjects were instructed to maintain the contraction for an additional 1 s before relaxing. The isometric torque generated was measured with a load cell attached to the movement arm of the machine and displayed to the subjects as concurrent visual feedback on a video display terminal. Following each isometric contraction, a 10 s rest interval was provided while the next testing angle was set. The testing positions were standardized with a mechanical goniometer attached to the movement arm of the testing machine.

**Training.** Following completion of the pretraining strength tests, subjects were randomly assigned to one of three training groups or a control group that did not train. The assignment of subjects to groups was done with the restriction that twice as many subjects would be included in the training groups than in the control group ($n$ = 10). Group A ($n$ = 18) trained the lumbar extensors in a ROM limited between 72° and 36° of lumbar flexion, group B ($n$ = 14) trained the lumbar extensors in a ROM limited between 36° and 0° of lumbar flexion, and group AB ($n$ = 16) trained through a 72° ROM. Group characteristics are presented by gender in Table 1.

Previous research has shown that improvements in isometric lumbar extension strength are similar for isometric and dynamic lumbar extension strength training (5). Because most daily activities involve dynamic muscle actions, an isotonic training regimen was employed in this study. Training was conducted on the same lumbar extension machine that was used for testing. Resistance was provided by a weight stack attached to the movement arm of the machine, and resistive torque was varied with a cam supplied by the manufacturer. The cam varied the resistance by a 1.4:1.0 ratio from flexion (72° of flexion) to extension (0° of flexion). A removable range limiting device designed to sit on top of the weight stack and allow 36° of lumbar movement (72–36° of lumbar flexion) was used for training group A. For group B, the movement arm of the lumbar machine was positioned and locked into place at 36° of lumbar flexion, thus allowing 36° of movement between 36–0° of lumbar flexion.

Subjects trained once per week for 12 wk. During each training session, subjects completed one set of lumbar extensions through their respective ROM with an amount of weight that allowed 8–12 repetitions to volitional muscular fatigue. Each repetition was performed in a slow controlled manner with 2 s required for the concentric portion of the lift (lifting the weight) and 4 s required for the eccentric portion of the lift (lowering the weight). When subjects could complete more than 12 repetitions with a given amount of weight, the weight load was increased by approximately 5%. Low frequency/low volume training was employed for the following reasons: 1) this type of training has previously produced significant improvements in isometric lumbar extension strength (5,10); 2) the improvements noted with this type of training in beginning exercisers are similar to those noted with more frequent training (5) and training with multiple sets (3); and 3) this type of training is currently employed in rehabilitation programs for LBP patients (11). All training sessions were supervised by experienced laboratory personnel.

TABLE 1. Group characteristics.

| Group | | N | Age (yr) | Height (cm) | Weight (kg) |
|---|---|---|---|---|---|
| A | Men | 12 | 31 ± 9 | 176.4 ± 8.1 | 86.5 ± 19.0 |
| | Women | 6 | 34 ± 17 | 164.7 ± 4.6 | 60.8 ± 11.6 |
| | Total | 18 | 32 ± 12 | 172.5 ± 9.0 | 78.9 ± 20.7 |
| B | Men | 8 | 32 ± 20 | 181.0 ± 5.6 | 79.1 ± 9.5 |
| | Women | 6 | 26 ± 7 | 167.6 ± 4.1 | 54.8 ± 6.1 |
| | Total | 14 | 30 ± 16 | 175.4 ± 8.4 | 68.7 ± 14.8 |
| AB | Men | 9 | 27 ± 8 | 180.3 ± 6.2 | 75.6 ± 14.0 |
| | Women | 7 | 29 ± 7 | 164.2 ± 7.8 | 60.8 ± 11.3 |
| | Total | 16 | 28 ± 8 | 172.2 ± 10.7 | 69.1 ± 14.6 |
| C | Men | 4 | 39 ± 3 | 174.9 ± 5.4 | 79.5 ± 9.5 |
| | Women | 6 | 26 ± 5 | 160.6 ± 5.8 | 53.6 ± 3.6 |
| | Total | 10 | 31 ± 8 | 166.3 ± 9.1 | 63.9 ± 14.7 |

Values are means ± SD.

Following the 12 wk of training, each subject completed two post-training isometric strength tests (one in each of the two testing orders). The procedure used for the post-training tests was identical to that used for the second and third pretraining strength tests.

**Treatment of the data.** Isometric torque was measured in ft · $lb^{-1}$ and converted to Newton · meters (N · m). Training loads were obtained from the weight stack of the training machine without consideration of the mechanical advantage offered by the cam used to vary the resistance. Reliability of the repeated measurements of isometric torque at each joint angle was determined by the calculation of intraclass correlation coefficients. The effect of order of testing on the isometric lumbar extension strength curve was evaluated for the pre- and post-training strength tests by using analysis of variance with repeated measures. Order 1 and order 2 tests were averaged to obtain criterion measures of pretraining and post-training strength. Changes in isometric lumbar extension strength at each of the seven angles measured and changes in the weight loads used for training were analyzed for group effects by analysis of covariance. Pretraining strength values were used as the covariates. Statistical significance was accepted at $P \leq 0.05$. If an F-value was significant, single degree of freedom comparisons were made with a least squares means procedure (12).

## RESULTS

**Order of testing.** Pretraining order 1 and order 2 isometric lumbar extension strength tests are illustrated in Figure 2. Reliability (intraclass correlation) coefficients between the two tests were high (R ≥ 0.92) at each angle of measurement except for 0° of lumbar flexion, where the reliability was R = 0.81. Analysis of variance revealed a significant order-by-angle interaction ($P \leq 0.01$), and paired $t$-tests at each angle test was significantly higher at 72° of lumbar flexion and significantly lower at 36°, 24°, 12°, and 0° of lumbar flexion. An order-by-angle interaction was also present for the post-training data ($n$ = 50 with controls excluded). Examination of the three-way interaction including time (time-by-order-by-angle) indicated that the order of testing effect was not influenced by training ($P >$ 0.05).

**Limited range-of-motion training.** The four groups did not differ statistically with respect to age, height, and weight (Table 1). There were no statistically signif-

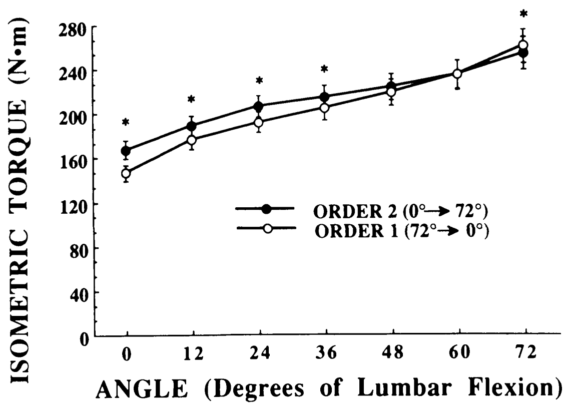


**Figure 2—Order 1 and order 2 isometric torque values obtained through 72° of lumbar motion ($n$ = 58). Order 1 tests began at 72° of lumbar flexion and progressed to 0° of lumbar flexion. Order 2 tests began at 0° of lumbar flexion and progressed to 72° of lumbar flexion. *$P \leq 0.05$**

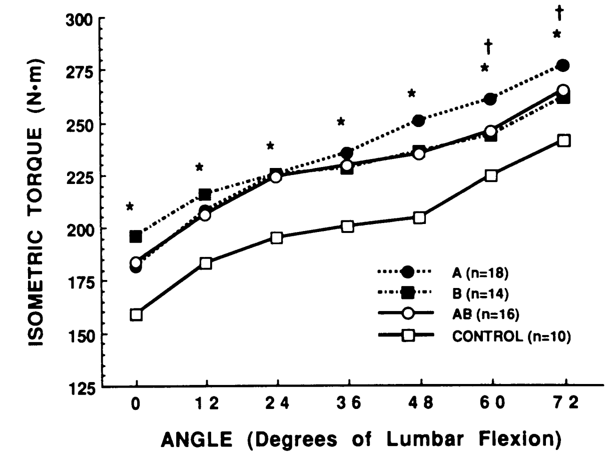


**Figure 3—Adjusted post-training isometric torque values (from analysis of covariance) for the limited ROM training (A and B), full ROM training (AB), and control groups. Group A trained through a ROM limited between 72° and 36° of lumbar flexion. Group B trained through a ROM limited between 36° and 0° of lumbar flexion. Group AB trained through a 72° range of lumbar motion. *Control < A, B, AB ($P \leq 0.05$). A > B ($P \leq 0.05$).**

icant interactions among groups involving gender. Therefore, the data were pooled for men and women for further analysis. Adjusted post-training isometric torque values for each group are presented in Figure 3. All training groups (A, B, and AB) showed a significant improvement in isometric strength at each angle measured when compared with the controls. The greatest gains in strength were noted for A and B in their respective ranges of training, but A and B did not differ significantly from AB ($P > 0.05$) at any angle. Group A was significantly greater than group B at 72° and 60° of flexion. Relative increases in isometric strength ranged from 11.0% for A, 3.7% for B, and 4.9% for AB at 72° of flexion to 22.1% for A, 28.0% for B, and 22.1% for AB at 0° of flexion. The weight loads used during training (Table 2) improved significantly ($P \leq 0.05$) and to a similar extent for each of the three training groups (A = 36.6%, B = 42.1%, and AB = 33.4%).

TABLE 2. Training load and number of repetitions completed during the first (pretraining) and last (post-training) week of training.

| | Pretraining | | Post-Training | | |
|---|---|---|---|---|---|
| Group | Wt (kg) | Reps | Wt (kg) | Reps | Δwt[a] |
| A ($n$ = 18) | 67.4 | 14.5 | 90.2 | 11.6 | 36.6 |
| | ±23.3 | ±6.5 | ±30.6 | ±3.1 | ±20.3 |
| B ($n$ = 14) | 64.4 | 19.6 | 89.4 | 11.8 | 42.1 |
| | ±24.5 | ±10.6 | ±31.7 | ±2.5 | ±25.5 |
| AB ($n$ = 16) | 65.4 | 14.4 | 85.4 | 11.6 | 33.4 |
| | ±23.3 | ±5.7 | ±25.7 | ±2.2 | ±15.6 |

Values are means ± SD.
[a] Δwt represents the relative (%) change in training load.

## DISCUSSION

Measurements of isometric strength at different joint angles are often used to describe strength through a given ROM (9). Previous research involving the quantification of knee extension strength has shown that fatigue associated with multiple joint angle isometric testing can influence the shape of the isometric strength curve (6). The present data indicate that the isometric lumbar extension strength curve is also influenced by fatigue associated with multiple joint angle testing. This warrants consideration when a multiple joint angle isometric test is used to describe lumbar extension strength at various positions throughout a ROM. When maximal strength measures are desired from multiple joint angle testing, longer rest intervals between contractions may be required.

The normal isometric lumbar extension strength curve is descending from flexion to extension (4). The slope of the descending curve is less when testing is conducted from extension (0° of lumbar flexion) to flexion (72° of lumbar flexion), giving the appearance of a flatter curve and a more uniform distribution of strength throughout the ROM than when testing is conducted from flexion to extension. Thus, the shape of the isometric lumbar extension strength curve is influenced by the order of multiple joint angle testing. The repeated measurements of isometric lumbar extension strength made at multiple joint angles were highly reliable, even when the testing is conducted in different orders. Although test reliability does not guarantee the validity of maximal force production, this finding is consistent with previous research on the reliability of isometric strength testing of the knee extensor muscles at multiple joint angles (6).

Because of the importance of evaluating strength throughout a 72° ROM in the present study, strength testing was conducted in opposing orders to obtain criterion measures for analysis. An important finding of the present study was that 12 wk of lumbar extension training did not influence the order of testing effect on the shape of the lumbar extension strength curve. We were concerned that an improvement in muscular endurance resulting from the resistance training might diminish the effect of fatigue during multiple joint angle testing. This was not the case following 12 wk of training. Therefore, as long as the order of testing is standardized, a single multiple joint angle test can be used to evaluate various treatment effects on lumbar extension strength through a ROM even though the force curve generated will be related and the specific testing conditions employed.

The training results showed that all groups were able to increase their isometric lumbar extension strength throughout the ROM when compared with controls. This finding indicates that a significant carryover of strength occurred into the untrained ROM for the limited ROM training groups. Similar results have been reported following limited ROM training with the knee extensor muscles (6).

A finding of the present study that differed from that of previous work with the knee extensors was the fact that the strength gained from limited ROM training was similar to that of full ROM training throughout the entire ROM. This is indicative of a nonspecific training response for limited ROM lumbar extension training. When the knee extensors were trained with a dynamic resistance through a restricted ROM, the carryover of strength into the untrained ROM was limited and not as great as that resulting from full ROM training (6). The knee extensors, however, were trained through a 60° ROM and tested through a 120° ROM. Thus, there was a significantly greater ROM that was not trained (60°) compared with the 36° ROM that was tested but not trained by groups A and B in the present study.

Previous work with isometric exercise has resulted in a carryover of strength to only 20° on either side of the joint angle trained (8). It is of interest to note from Figure 3 that beyond 20° from the ROM trained in the present study significant differences among groups began to appear. At 72° and 60° of lumbar flexion (24–36° from the trained ROM for group B) group A was able to generate more torque than group B. At 0° of lumbar flexion (36° from the trained ROM for group A) there was a trend ($P = 0.09$) for the observed torque for group A to be less than that noted for group B.

The length of the active muscle is an important mechanical factor that influences the amount of external force a muscle can produce. Thépaut-Mathieu et al. (15) have shown that myoelectrical (EMG) as well as mechanical changes are linked to length-specificity during resistance exercise training. It is doubtful that metabolic transformation (morphological adaptation) of the muscle fibers could explain the total ROM training specificity resulting from low frequency short duration (12 wk) training.

The training response to limited ROM lumbar extensor exercise may have important clinical implications. Many LBP patients are limited in their range of lumbar motion (11,13). The findings of the present study indicate that people who are able to train through a ROM limited to only 36° of lumbar motion may still obtain a full ROM training benefit. Thus, conservative progression in ROM will not compromise strength gain in the ROM that is not exercised. However, full ROM exercise is a prudent goal to achieve and maintain flexibility and joint mobility.

Although one would expect a similar ROM training response in a patient population, it is now important to confirm with further research that LBP patients do, in fact, show strength gains in the untrained ROM as their ROM improves. The etiology of LBP is diverse, and in some cases the cause of LBP may limit training adaptation. The intensity of lumbar extension training prescribed for LBP patients may also be more conservative (lower) than that employed in the present study (11). The influence of exercise intensity on limited ROM training responses has not been studied.

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