Effect of 12 and 20 Weeks of Resistance Training on Lumbar Extension Torque Production

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This study compared the effect of varied training frequencies on the development of isometric lumbar extension torque (strength) over 12- and 20-week training periods. Fifty-six subjects were randomly assigned to training once every other week (training group 1, n=10), once per week (training group 2, n=12), twice per week (training group 3, n=12), or three times per week (training group 4, n=7) or to a nontraining control group (n=15). Training consisted of one set of 8 to 12 variable-resistance lumbar extensions to volitional muscular fatigue. Prior to and following 12 and 20 weeks of training, subjects were given a test that evaluated isolated isometric lumbar extension torque in a seated position at seven positions (angles) through a 72-degree range of motion. The control group showed no change in isometric torque. All training groups showed significant increases in lumbar extension torque at 12 and 20 weeks of training, whereas no significant differences were found among the groups with respect to the magnitude of torque gained. Pooled training data showed a significant time×angle interaction at 12 weeks and a continuing trend at 20 weeks, indicating that the shape of the isometric torque-angle curve changed as a result of training. This effect was due to greater increases in isometric torque at the fully extended position than at the fully flexed position at 12 weeks (92% versus 16%, respectively) and at 20 weeks (123% versus 17%, respectively). These findings show that isometric lumbar extension torque increases occur mainly within the first 12 weeks of training, although additional gains in the more extended positions can be expected when training is continued through 20 weeks. These data also indicate that training once every other week or once per week is as effective as training twice per week or three times per week for increasing isometric lumbar extension torque over 20 weeks. [Carpenter DM, Graves JE, Pollock ML, et al. Effect of 12 and 20 weeks of resistance training on lumbar extension torque production. Phys Ther. 1991;71:580–588.]

Key Words: *Exercise frequency, Isometric exercise, Low back, Resistance training.*

Poor muscle function is often credited as a risk factor for low back pain (LBP).[1-4] Although research has not yet established a definitive relationship between muscular strength of the spine and LBP, it has been estimated that more than 80% of all LBP cases are caused by weak trunk muscles, as opposed to structural disorders.[5] Numerous studies[1,2,4,6-8] have suggested that improved strength and endurance of the trunk musculature will aid in the prevention and treatment of LPB. These findings have focused attention on programs designed to increase the strength and mobility of the lumbar spine.

Passive–range-of-motion (ROM) and calisthenic-type exercise programs are popular in rehabilitative settings and have been reported to alleviate the symptoms of LBP.[9,10] Unfortunately, such programs do not provide progressive resistance for the lumbar musculature and thus are limited in their ability to increase lumbar strength. Few studies have attempted to increase the strength of the lumbar extensor muscles through progressive-resistance training. Early attempts by Flint[11] and Berger[12] showed significant increases in trunk extension strength as a result of progressive-resistance training. These studies, however, did not isolate the lumbar musculature by stabilizing the pelvis and measured strength through a limited ROM.

Recent studies by Pollock et al[13] and Graves et al[14] indicate that the lumbar extensor muscles are chronically weak and show a large potential for improvement in torque-generating capacity when they are isolated through pelvic stabilization and exercised using a progressive-resistance training program. Both of these studies used a multiple-joint-angle isometric test to quantify lumbar extension torque through a 72-degree ROM. Interestingly, Graves et al[14] found no significant differences in isometric torque gains among groups that trained once every 2 weeks, one time per week, two times per week, and three times per week. These findings are contrary to those of studies investigating optimal training frequencies for other muscle groups.[15] In addition, although the lumbar extension torque increases reported by Pollock et al[13] and Graves et al[14] were substantially greater at 0 degrees of lumbar flexion than at 72 degrees of lumbar flexion, no statistically significant change in the shape of the isometric lumbar extension torque-angle curve was noted.

To date, the effects of progressive-resistance lumbar extension training programs beyond 12 weeks have not been reported in the literature. Potential benefits associated with continued training would aid therapists in designing appropriate treatment programs. This information is of particular significance in light of the fact that therapeutic strengthening programs are typically implemented within a 12-week period. The purpose of this study was to extend the work of Pollock et al[13] and Graves et al[14] by investigating the effects of lumbar extension training beyond 12 weeks. Our specific aims were (1) to determine how a longer training period would affect lumbar extension torque using varied training frequencies and (2) to determine whether a longer training period would affect the shape of the isometric lumbar extension torque-angle curve.

Method

Subjects

All subjects were volunteers from the University of Florida and Gainesville, Fla, community. One hundred subjects (64 men, 36 women) completed the initial testing and 12-week training period, as reported by Graves et al.[14] Eighty-five subjects participated in the training, and 15 subjects served as controls. Following 12 weeks of training, 55 subjects (33 men, 22 women) elected to extend their training period to 20 weeks. Fourteen of these subjects (10 men, 4 women) were unable to attend all testing or training sessions and were discontinued from the study. Of these 14 subjects, 5 were in the group that trained three times per week, 3 were in the group that trained two times per week, 3 were in the group that trained one time per week, and 3 were in the group that trained once every 2 weeks. The 41 subjects (23 men, 18 women) who completed all testing and training over the 20-week period constituted the sample for this study. Descriptive characteristics of the subjects are provided in Table 1. All subjects were previously untrained and free from chronic LBP, overt cardiovascular disease, or any orthopedic contraindications to exercise. Written informed consent was obtained from each subject.

Procedure

Testing. Prior to the training period, all subjects completed three isometric lumbar extension torque-production tests. The first two tests were completed on the same day, with a 20-minute rest period between tests. The third test was completed on a second testing day. These two testing sessions were separated by at least 72 hours to allow subjects to recover from any fatigue associated with the testing. Each test measured maximal voluntary isometric lumbar extension torque at seven positions (angles) through a 72-degree ROM. The testing positions began at 72 degrees and progressed to 60, 48, 36, 24, 12, and 0 degrees of lumbar flexion.

Subjects were instructed to refrain from strenuous physical activity for at least 24 hours prior to each test session. After reporting to the laboratory, subjects were seated in a specially designed lumbar extension machine,* and their knees were positioned so that the femurs were parallel to the

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Table 1. *Characteristics of Control and Training Groups*

Variable	Control	Training Group[a] 1	2	3	4	Combined[b]
No. of subjects						
M	10	6	4	7	6	23
F	5	4	8	5	1	18
Age (y)						
$\bar{X}$	29.1	31.9	33.3	38.0	38.6	35.2
SD	9.9	9.7	7.2	7.2	11.0	8.7
Range	19-46	20-47	24-49	30-48	24-53	20-53
Height (cm)						
$\bar{X}$	177.2	176.5	170.8	174.3	177.2	174.4
SD	3.7	10.4	11.0	7.4	6.7	9.2
Range	173-183	164-193	144-186	163-185	168-186	144-193
Weight (kg)						
$\bar{X}$	77.2	74.9	68.6	72.7	77.2	73.0
SD	8.2	20.3	14.2	12.3	13.4	15.1
Range	61-88	49-112	44-89	57-91	58-91	44-112

[a]Training group 1 trained once every other week, training group 2 trained once per week, training group 3 trained twice per week, and training group 4 trained three times per week.

[b]Pooled training group data.

seat (Fig. 1). The subjects were then secured in place by femur, pelvic, and thigh restraints that stabilized the pelvis. A head rest was adjusted to the level of the occipital bone for comfort and support. This stabilization procedure has been described in detail by Pollock et al[13] and Graves et al.[16]

Once the pelvis was stabilized and the testing position was standardized, each subject was moved into a neutral, upright posture (between 18° and 36° of flexion), and the center line of his or her 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 degrees of lumbar flexion. The counterweight was adjusted while the subject rested against the upper-back pad at 0 degrees 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 positioned at 72 degrees of lumbar flexion and instructed to slowly and continuously extend their back against the upper-back pad for 2 to 3 seconds. Once peak torque had been achieved and registered, subjects were instructed to maintain the contraction for an additional 1 to 2 seconds before slowly relaxing. A 10-second rest interval was provided between each isometric contraction while the next angle of measurement was set. During each contraction, concurrent visual feedback was provided on a video display screen, and subjects were verbally encouraged to give a maximal effort. To ensure pelvic stabilization, the thigh and femur restraints were tightened if pelvic movement was observed during testing. This movement was easily checked by noting any rotation of the pelvic restraint. Following 12 weeks and 20 weeks of training, subjects in the training groups performed an isometric torque-production test on two separate occasions using the same procedure as that outlined for the pretraining tests. Subjects in the control group were only retested at 12 weeks.

Training. Following the pretraining testing sessions, subjects were rank-ordered by peak isometric torque and randomly assigned to training once every other week (training group 1, n=10), once per week (training group 2, n=12), twice per week (training group 3, n=12), or three times per week (training group 4, n=7) or to a nontraining control group (n=15).

Training was conducted over a 20-week period. After reporting to the laboratory for each training session, subjects were seated in the lumbar extension machine and secured as described previously. For each training session, subjects were required to perform one set of lumbar extensions through the 72-degree ROM with a weight load that allowed 8 to 12 repetitions to volitional muscular fatigue. *Volitional muscular fatigue* was defined as the inability of the subject to complete a lumbar extension through the entire 72-degree ROM. Variable resistance was achieved through the use of a cam housed within the machine. Each repetition was performed in a slow, controlled manner, allowing 2 seconds for the positive (concentric) movement, a brief (1-second) pause, and 4 seconds for the negative (eccentric) movement. Exercise cadence was monitored by recording the total exercise time of each training session. The weight load was increased by 5% when 12 or more repetitions could be completed. Subjects were supervised and encouraged by experienced laboratory personnel to provide a maximal effort during each training session.

Data Analysis

Descriptive characteristics of the subjects (age, height, and weight) were analyzed using analyses of variance (ANOVAs). The first two pretraining tests completed by the subjects were considered a practice session to familiarize the subjects with the lumbar extension machine and testing proto-

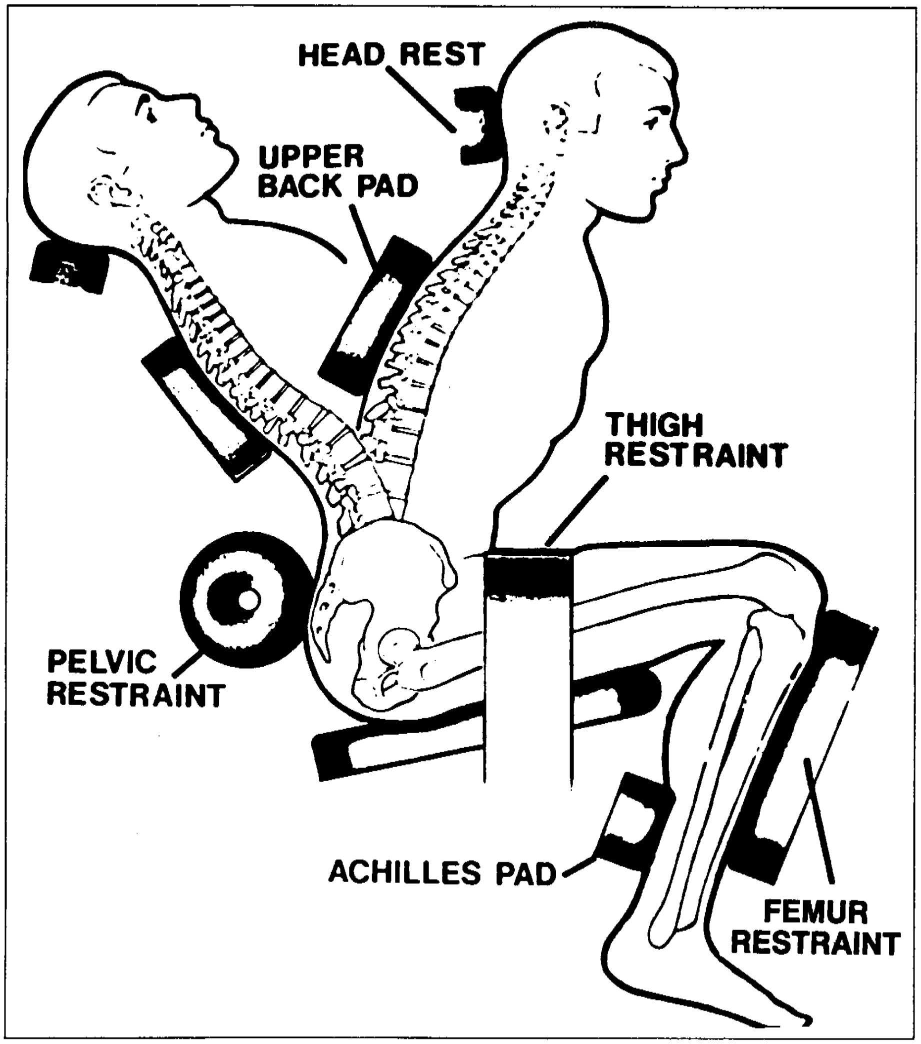

Figure 1. *Restraint system of the MedX™ lumbar extension machine.*

col. The third pretraining test was used as a baseline criterion measure. Measurements obtained by our testing protocol have previously been shown to be highly reliable (r=.94-.98) at all positions, with a low degree of variability (standard error of the estimate=7%-12% of the mean torque values).[16] The isometric test yielding the greatest cumulative torque values over the seven testing angles was considered to be the subject's best effort and was used as the criterion test for 12- and 20-week torque production.

Isometric torque was measured in foot-pounds and converted to newton-meters. Means and standard deviations were calculated for each angle of measurement prior to and following 12 and 20 weeks of training. Relative changes in isometric torque for each angle of measurement were calculated for each individual at 12 and 20 weeks. Changes in isometric torque and changes in average training weight were analyzed for the 12- and 20-week training periods within each group using ANOVAs for repeated measures. Because of initial differences in isometric torque ($P \leq .05$), comparisons were made among groups by analyses of covariance (ANCOVAs). The pretraining criterion torque measures were used as the covariates. Data for all training groups were pooled into a combined group, and the time×angle interaction was used to evaluate the shape of the isometric torque-angle curve following 12 and 20 weeks of training. Changes in the average training weights for the 12- and 20-week training periods were analyzed using ANCOVAs, with the average training weights for the first week used as the covariates. The ANOVAs and ANCOVAs were performed using the SAS[17] general linear model procedure. A probability value of .05 was required for statistical significance. If an F value was significant for repeated-measure designs, single-degree-of-freedom comparisons were made using specified contrasts in the general linear model procedure. A *post hoc* analysis for the training weights was performed using a least-squared-means procedure.

Results

The ANOVAs revealed no significant differences among the control and combined training groups with respect to age, height, and weight. Pretraining, 12-week, and 20-week mean isometric torque values at each angle measured for the training groups and pretraining and 12-week torque values for the control group are presented in Table 2. The ANOVAs revealed that, after 12 weeks of training, the control group showed no significant change ($P>.05$) in isometric torque at any of the angles tested. We assumed that the control group subjects would continue not to change, and only the training groups were tested again at 20 weeks. After 12 weeks of training, the ANCOVAs revealed that all training groups showed a significant increase ($P<.05$) in isometric torque at each angle measured when compared with the control group. Among-group ANCOVAs revealed that the training groups responded similarly to the training at 12 and 20 weeks ($P>.05$).

Analyses of covariance for adjusted 12-week isometric torques revealed that the combined group, when compared with the control group, demonstrated a significant ($P<.05$) increase in isometric torque at each test angle measured throughout the 72-degree ROM. Figure 2 shows the results of the within-group ANOVA of the treatment effect for the combined group. At 12 weeks, a significant increase ($P<.0001$) in isometric torque from pretraining values occurred at each

Table 2. *Pretraining (PRE), 12-Week, and 20-Week Isometric Torque Values (in Newton-meters) for the Training Groups and PRE and 12-Week Values for the Control Group ($\bar{X}$±SD)*

	Isometric Torque (Degrees of Lumbar Flexion)						
Group[a]	**0°**	**12°**	**24°**	**36°**	**48°**	**60°**	**72°**
Control (n=15)							
PRE	209.4±104.1	271.8±103.4	304.3±114.2	317.7±131.7	341.7±141.5	374.1±154.3	412.7±150.7
12-Week	212.7±81.3	264.7±70.4	292.6±79.8	322.3±91.5	350.2±112.6	381.5±122.5	405.6±126.6
1 (n=10)							
PRE	157.7±69.2	228.7±94.2	262.5±101.3	307.2±139.7	317.5±139.9	349.9±163.1	384.9±205.0
12-Week	263.8±121.6	295.8±128.7	319.6±136.6	337.6±165.3	356.1±182.5	384.4±204.2	418.6±238.1
20-Week	284.1±122.4	321.0±131.2	342.8±145.4	357.4±154.8	370.2±167.3	388.2±189.3	416.3±224.2
2 (n=12)							
PRE	134.3±86.3	182.6±88.4	216.2±96.0	235.5±101.7	251.2±106.3	271.6±110.0	282.1±114.5
12-Week	198.5±74.5	247.0±72.2	266.4±83.5	283.7±87.6	297.8±101.8	323.1±114.2	249.1±120.1
20-Week	247.5±81.7	273.3±84.3	294.6±96.6	308.6±98.8	326.9±111.6	330.6±102.9	345.7±105.4
3 (n=12)							
PRE	177.8±82.3	233.9±96.2	269.4±107.7	295.2±116.8	315.6±127.4	345.8±148.7	373.8±166.5
12-Week	240.0±91.7	312.5±134.4	337.3±142.9	356.9±148.6	370.8±165.8	391.7±175.0	414.6±195.7
20-Week	294.1±116.3	332.8±128.5	360.3±134.8	372.0±149.1	380.3±152.0	403.9±170.4	412.2±174.5
4 (n=7)							
PRE	158.3±73.9	252.8±76.7	292.7±95.9	327.4±116.4	361.6±136.1	389.1±157.6	415.1±184.9
12-Week	313.2±104.4	347.6±104.8	371.9±120.7	394.3±128.1	418.7±139.1	434.2±136.4	464.2±159.5
20-Week	339.2±92.7	359.7±118.1	380.1±120.1	395.1±127.4	416.3±126.0	438.4±134.5	476.2±158.2

[a]See Tab. 1 footnote for description of training groups.

angle tested. There was a significant ($P<.05$) time×angle interaction at 12 weeks, indicating that the shape of the torque-angle curve changed as a result of the training. This effect was caused by the greater increases in isometric torque in the latter half of the ROM (48°-0°) than in the first half of the ROM. Relative changes in isometric torque for the combined group ranged from 16.4% at full flexion (72°) to 91.9% at full extension (0°) (Tab. 3).

The ANOVAs for the 20-week torque values revealed that the combined group continued to show an increase ($P<.05$) in isometric torque at five of the seven angles tested (Fig. 2). A strong trend ($P=.09$) for a time×angle effect at 20 weeks and additional improvements in isometric torque in the latter half of the ROM (48°-0°) indicated that the shape of the torque-angle curve continued to change as a result of the 8 additional

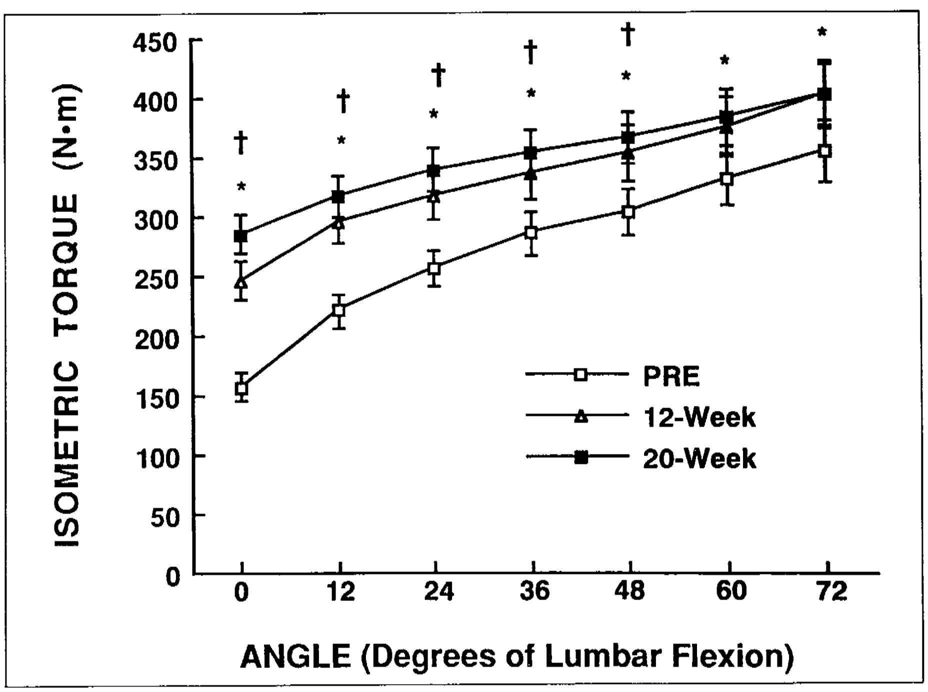

Figure 2. *Initial (PRE), 12-week, and 20-week isometric torques for the combined group. Asterisk indicates PRE<12-week, 20-week (P<.0001); dagger indicates 12-week<20-week (P<.05). Values represent mean±SEM.*

Table 3. *Changes in Isometric Torque (in Percentages) Relative to Pretraining Values ($\bar{X}$±SD)*

Group	Angle (Degrees of Lumbar Flexion)						
	0°	12°	24°	36°	48°	60°	72°
Control (n=15)							
12-Week	9.5±29.8	2.0±17.8	1.4±21.5	9.1±24.9	8.0±20.4	7.0±16.9	0.6±12.4
Combined (n=41)							
12-Week	91.9±125.6	40.9±38.7	28.1±27.3	21.4±24.7	18.1±21.2	15.6±17.7	16.4±18.3
20-Week	123.1±152.2	53.2±45.3	38.5±33.7	28.5±26.0	24.8±21.7	18.9±17.7	17.2±18.0

weeks of training. As in the 12-week results, this trend was supported by the greater increase at 0 degrees of flexion (123.1%) than at 72 degrees of flexion (17.2%) (Tab. 3). When relative changes in isometric torque at 20 weeks were compared with the 12-week values, the combined group data showed an additional 31.2% improvement at the fully extended position (0°) (P<.05) compared with only a 0.8% improvement at the fully flexed position (72°) (P>.05).

Training responses for each training group during the 1st, 12th, and 20th weeks are presented in Table 4. The ANOVAs revealed a significant increase (P≤.05) in the average weight lifted throughout the ROM for training at 12 and 20 weeks compared with initial values for all groups. Among-group ANCOVAs revealed that training group 1 increased in training weight to a lesser extent than training groups 3 and 4 at 12 weeks and training group 3 at 20 weeks. Additional increases in training weights were small (P>.05) from 12 to 20 weeks.

Discussion

Resistance training programs have been shown to produce significant gains in lumbar extensor strength when these muscles are effectively isolated by pelvic stabilization.[13,14] Few studies, however, have been conducted to determine the most effective training frequency for lumbar extensor torque development. Only Graves et al[14] have investigated the effect of varied training frequencies (ie, once every other week, once per week, twice per week, and three times per week) on lumbar extensor torque. Following 12 weeks of training in their study, isometric lumbar extension torque increased significantly in all groups, although no differences existed among the groups. The results of our investigation extend these findings. After 20 weeks of variable-resistance lumbar extension training, the magnitudes of isometric torque gained by all groups were similar at each test point throughout the ROM. These data indicate that one set of 8 to 12 variable-resistance lumbar extensions performed to volitional fatigue at the low training frequencies of once every other week and once per week is as effective for increasing isometric lumbar extension torque as training two or three times per week. We believe that statistical significance among groups was difficult to achieve because of the relatively small subsample (group) sizes (n=7-15). Given the magnitude of the observed mean differences among groups, however, the sample size required to achieve statistical significance at .05 would be very large and perhaps unrealistic for a 20-week training study. For example, using the data obtained from our study, with alpha (α) and beta (β) levels of

Table 4. *Average Beginning, 12-Week, and 20-Week Training Weights and Repetitions for Training Groups ($\bar{X}$±SD)*

	Training Group[a]			
	1 (n=10)	2 (n=12)	3 (n=12)	4 (n=7)
Beginning weight (kg)	73.6±24.7	58.9±18.0	69.9±27.5	78.2±21.4
12-Week weight (kg)	93.6[b,c]±32.8	84.8[b]±24.3	100.7[b]±37.4	112.3[b]±29.9
20-Week weight (kg)	98.2[b,d]±38.9	86.2[b]±28.0	105.9[b]±40.8	115.8[b]±31.3
Beginning repetition	16.6±6.8	15.6±4.3	16.4±4.4	17.1±2.8
12-Week repetition	12.4[e]±3.4	10.9[e]±2.2	11.6[e]±2.0	11.2[e]±1.6
20-Week repetition	11.1[e]±2.9	11.2[e]±2.2	10.8[e]±1.3	10.5[e]±1.7

[a]See Tab. 1 footnote for description of training groups.

[b]12, 20 weeks>beginning, P<.05.

[c]Change from beginning to 12 weeks for training group 1<change from beginning to 12 weeks for training groups 3 and 4 when adjusted for initial differences in strength using analysis of covariance (ANCOVA), P<.05.

[d]Change from 12 to 20 weeks for training group 1<change from 12 to 20 weeks for training group 3 when adjusted for initial differences in strength using ANCOVA, P<.05.

[e]12, 20 weeks<beginning, P<.05.

significance both set at 5% (α=.05, β=.95) and a calculated effect size (d) of .70, a subsample size of 46 subjects per group would have been required for a two-tailed test of significance.[18]

Our findings are in contrast to those of strength training programs typically prescribed for other muscle groups, which show optimal training frequencies of two times per week or more. Gillam[19] found that training frequencies of three and five times per week were superior to training frequencies of one and two times per week for developing 1-repetition maximum bench-press strength in male high-school students over a 9-week training period. Braith et al[20] compared the effects of two-times-per-week versus three-times-per-week variable-resistance knee extension training on peak isometric torque in young men and women (age=18-38 years). Following 10 and 18 weeks of training, the magnitude of torque gained for the three-times-per-week training group was significantly greater than that gained for the two-times-per-week training group. In a review of the literature on resistance training, Fleck and Kraemer[15] reported that three times per week is the minimum training frequency required for maximal gains in strength over a 12-week training period.

The abnormally large isometric torque increases associated with the low training frequencies of once every other week and once per week found in this study reflect a poor initial torque level of the lumbar extensor musculature. Trunk extension movements without pelvic stabilization primarily exercise the hip extensor (gluteal and hamstring) muscles.[21-23] When the pelvis is stabilized as in our study, however, the lumbar extensors can be effectively isolated and trained. This stabilization, in conjunction with the progressive-resistance training protocol, constituted a highly effective stimulus to the lumbar extensor musculature. It is plausible that the consistent, specific nature of this stimulus creates a greater amount of fatigue than is normally found with other muscle groups and necessitates a longer recovery period between training sessions. Consequently, isolated lumbar extension training at relatively low training frequencies (eg, once every other week or once per week) appears to be sufficient to elicit significant improvements in isometric lumbar extension torque. Although no statistically significant differences in isometric torque gains were noted among the training groups, previous research has indicated that isolated lumbar extension training at frequencies greater than once per week may increase the risk of chronic fatigue and result in symptoms of overtraining.[14]

The data presented in Table 4 indicate that the average training weight increased for all training groups at 12 and 20 weeks compared with beginning values. The improvements in training weights within the first 12 weeks, however, were accompanied by a significant decrease in the number of repetitions performed and therefore should be interpreted cautiously. It is likely that the initial improvements were, in part, a reflection of the reduced number of repetitions.

Because no differences were noted among training groups with respect to the amount of isometric torque gained over the 20-week training period, data were pooled into a combined training group for further analysis. The combined group showed isometric torque increases of 16% to 17% at 72 degrees of lumbar flexion and of 92% to 123% at 0 degrees of lumbar flexion over the 12- and 20-week training periods, respectively. These data are in agreement with previous research[13,14] demonstrating that variable-resistance training of the isolated lumbar extensor muscles can yield isometric torque gains ranging from 12% to 42% at 72 degrees of lumbar flexion and from 54% to 130% at 0 degrees of lumbar flexion within 12 weeks. These isometric torque gains are far greater than the average improvement of 7% to 28% shown with other trunk extension studies that did not isolate the lumbar muscles with pelvic stabilization[11,12] or the 15% to 31% improvement shown with studies involving other muscle groups (see review by Fleck and Kraemer[15]). DeVries[24] has summarized the work of Mueller and Rohmert,[25] who reported an inverse relationship among the rate of strength gain, initial level of strength, and training duration. Mueller and Rohmert reported the increase in relative strength from isometric training (one maximal 1-second contraction daily) of the trunk extensor muscles over a 5½-week period. They found that the average percentage of gain per week decreased exponentially as training progressed. Mueller and Rohmert concluded that untrained muscle will gain strength at a much faster rate and to a greater degree than trained muscle. Thus, strength improvement is related to the initial level of fitness. We believe the magnitude of torque gains found in our study, particularly in the latter half of the ROM, reflect the untrained state (and strength potential) of the lumbar extensor muscles.

We considered whether the large increases in isometric lumbar extensor torque found in our study could be due, in part, to a learning effect. Following 10 weeks of lumbar extension exercise, Pollock et al[13] found large increases in lumbar extensor torque similar to those found in this study. Citing work by Graves et al[16] in which a relatively small increase in torque (8%-10%) occurred only from the first to the second of four testing days, Pollock and co-workers[13] dismissed the possibility of attributing the large increases in isometric torque to a "practice effect" associated with the isometric testing. We used a testing protocol adapted from that of Graves et al[16] that allowed an initial practice session to familiarize subjects with the isometric testing procedure prior to data collection. The fact that the control group showed no significant difference at any of the angles tested between the initial and 12-week testing periods, we believe, provides evidence that a practice effect did not affect the results.

It is generally accepted that increases in strength during the first 3 to 5 weeks of a resistance training program are due primarily to neuromuscular facilitation and that strength increases beyond 5 weeks are due primarily to morphological changes within the muscle.[26,27] Thus, it is likely that the initially large gains in isometric torque found in this study are partially attributable to neuromuscular adaptations associated with the exercise training. The degree to which each of these factors affected the large increases in isometric torque in this study is unknown. Because neuromuscular adaptations to resistance exercise occur early on in a training program, however, it is unlikely that this factor was responsible for the isometric torque increases that occurred beyond 12 weeks.

We speculated that the lumbar extensor muscles might respond more like a "normal" muscle group with respect to training frequency and the magnitude of torque gain following the initial 12 weeks of training. Clearly, this response did not occur. The similarity of torque increases among the training groups at 20 weeks and the additional 31% improvement in torque of the combined group at 0 degrees of lumbar flexion resulting from an additional 8 weeks of training (Fig. 2) indicate that the lumbar extensor muscles had not yet reached their full strength potential at 12 weeks. Further study is suggested to determine whether lumbar extension training at varied frequencies beyond 20 weeks affects the magnitude of lumbar extension torque development.

An interesting finding in this investigation was the change in the shape of the isometric lumbar extension torque-angle curve as a result of the training. Previously, we showed that the lumbar extensor muscles are much weaker in the extended positions than in the flexed positions.[13,14] Statistical analyses, however, indicated no time×angle effect. These results were likely affected by the relatively small sample used, which limited the statistical power of the analysis. When data were pooled into a combined group in the current investigation and the sample size was increased to 41, a time×angle effect was shown.

The flattening of the torque-angle curve in the extended positions following 12 weeks of training supports our contention that the lumbar extensor muscles are disproportionately weak in the mid to extended portions of the ROM. Expressed in different terms, the ratio of torque from 72 to 0 degrees of lumbar flexion was reduced from 2.3:1 prior to training to 1.6:1 at 12 weeks. Although a time×angle effect was not statistically significant at 20 weeks, a strong trend (P=.09) was apparent and was supported by additional torque increases at 48, 36, 24, 12, and 0 degrees (Fig. 2). At 20 weeks, the ratio of torque from 72 to 0 degrees had been further reduced to 1.4:1. This reduction of the torque ratio over the 20 weeks of training suggests the effectiveness of the 1.4:1 variable-resistance cam found in the lumbar extension machine.[23] These data indicate that, although torque levels may plateau in the first half of lumbar flexion following 12 weeks of training, continued improvements can be expected in the latter half of lumbar flexion with prolonged training. This finding has important implications for the design of lumbar strengthening and rehabilitation programs, in that training limited to shorter durations may realize only limited benefits. Additional research is needed to examine the effect of training on the lumbar extension torque ratio beyond 20 weeks.

The change in the torque-angle curve during the 20-week study period and the continued isometric torque increases beyond 12 weeks of lumbar extension training support previous research advocating the need for full ROM testing and training.[13,14,16,28] Isometric and isokinetic trunk extension strength is often described in terms of "peak" torque at a single joint angle.[1,2,29–33] Had we expressed isometric strength improvements with regard to peak torque (72°) only, our results would have indicated that training beyond 12 weeks would not further increase lumbar extension torque. Reporting only peak torque also would have misrepresented the potential for lumbar extension torque development. Furthermore, the disproportionate levels of torque throughout the ROM would not have been evident. This information would seem essential to those attempting to detect deficits or muscle imbalances throughout a given ROM. Our data support the efficacy of isometric multiple-joint-angle testing as a means of accurately evaluating and describing torque changes throughout a ROM.

Clinical Implications

Practical considerations often require health care professionals who utilize strengthening programs for the treatment of low back disorders to limit the frequency and extent of exercise. The significant increases in isometric torque with the low number of repetitions (8-12) and the low frequency (once every other week and once per week) of training used in this study may help guide therapists in designing more efficient treatment protocols. The continued increases in isometric torque beyond 12 weeks of training suggest that traditional therapeutic protocols for strengthening the low back may need to be extended for optimal results. The magnitude of torque gained and the reduction of the torque ratio (flattening of the torque-angle curve) from flexion (72° of lumbar flexion) to extension (0° of lumbar flexion) over the 20 weeks of training indicate that the lumbar extensor muscles are disproportionately weak throughout the ROM and possess an enormous potential for strength improvement. Because poor lumbar strength has been related to low back pathology, these findings should aid clinicians in the prevention and treatment of low pack pain.

Conclusions

This study extended the findings of previous research showing no differences in lumbar extension torque improvements among groups that trained once every other week, once per week, twice per week, or three times per week for 12 weeks. Eight weeks of additional training did not alter these results. These data indicate that one set of 8 to 12 variable-resistance lumbar extensions performed to volitional fatigue once every other week or once per week is an effective means of developing lumbar extension torque. The change (flattening) in the shape of the torque-angle curve consequent to 20 weeks of training indicates that the lumbar extensor muscles are disproportionately weaker at 0 degrees of lumbar flexion than at 72 degrees of lumbar flexion. Continued increases in lumbar torque from 12 to 20 weeks, particularly in the latter half of the ROM, represent the need for longer periods of full ROM lumbar extension training. The importance of pelvic stabilization and multiple-joint-angle testing for accurate quantification of full ROM testing and evaluation of training has been verified by these results. These findings have important implications for the design and implementation of lumbar extension strengthening and rehabilitation programs.

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