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# Effect of Training Frequency and Specificity on Isometric Lumbar Extension Strength

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**To investigate the effects of training frequency and specificity of training on isolated lumbar extension strength, 72 men (age = 31 ± 9 years) and 42 women (age = 28 ± 9 years) were tested before and after 12 weeks of training. Each test involved the measurement of maximum voluntary isometric torque at 72°, 60°, 48°, 36°, 24°, 12°, and 0° of lumbar flexion. After the pretraining tests, subjects were randomly stratified to groups that trained with variable resistance dynamic exercise every other week (1×/2 weeks, n = 19), once per week (1×/week, n = 22), twice per week (2×/week, n = 23) or three times per week (3×/week, n = 21); a group that trained isometrically once per week (n = 14); or a control group that did not train (n = 15). Analysis of covariance showed that all training groups improved their ability to generate isometric torque at each angle measured when compared with controls ($P < 0.05$). There was no statistical difference in adjusted posttraining isometric torques among the groups that trained ($P > 0.05$), but dynamic training weight increased to a lesser extent ($P < 0.08$) for the 1×/2 weeks group (26.6%) than for the groups that trained 1×/week, 2×/week, and 3×/week (37.2 to 41.4%). These data indicate that a training frequency as low as 1×/week provides an effective training stimulus for the development of lumbar extension strength. Improvements in strength noted after isometric training suggest that isometric exercise provides an effective alternative for developing lumbar strength. [Key words: lumbar extension training, frequency of training, specificity of training, variable resistance exercise, isometric exercise]**

LOW-BACK PAIN (LBP) is one of the most common and costly medical problems in modern industrialized societies. It has been estimated that 8 of 10 people will suffer from LBP at some time in their lives[20] at a cost of billions of dollars annually.[15,20] Although the etiology of LBP is diverse, many causes have been related to weakness or injury of the soft tissue in the lumbar area.[1,7,19,24,28–30,35] It is well documented that workers who do not have adequate strength relative to job demands are at a greater risk for low-back injury.[7,21,33,36] In addition, individuals with relatively high levels of muscular strength and endurance are less prone to back problems.[3,6,23,26] For these reasons, resistance training is often prescribed for the prevention and rehabilitation of LBP.[17,22,26,27] However, few studies have quantified changes in low-back strength to evaluate the effectiveness of low-back training.

It has been suggested that training the low back requires isolation of the lumbar muscles.[18,32] Technological developments involving pelvic stabilization and standardization of body position have facilitated lumbar muscle isolation for testing and training.[13,32] Recent research using this technology has shown that the lumbar extensors have an unusually large potential for strength gains.[32] Pollock et al[32] demonstrated that when the lumbar muscles are effectively isolated through pelvic stabilization, peak isometric lumbar extension strength can increase more than 40% after 10 weeks of training at a frequency of one training session per week. Strength increases in the weaker, extended position (0° of flexion) were 102%. Strength gains of this magnitude, in such a short period of time, are indicative of a low initial trained state (weakness) of the lumbar extensor muscles.[14]

The relatively low training frequency (one day per week) used by Pollock et al[32] is of particular interest. Resistance training is typically prescribed at a frequency of three times per week. Braith et al[5] reported that for low volume/high intensity knee extension training (1 set, 7–10 repetitions to volitional muscular fatigue), training three times per week is superior to training twice per week for up to 18 weeks of training. Although the amount of rest required between training sessions depends on the ability of the individual to recover from the overload imposed on the muscle,[8] 48 hours has been found to allow adequate recovery from exercise for most individuals beginning resistance training programs.[2] It is somewhat surprising, therefore, that such significant improvements in strength were found by Pollock et al[32] after training at a frequency of only 1 day per week.

Frequency of training is an important factor for the prescription of exercise. Appropriate training frequency for the lumbar muscles has application for healthy persons who may benefit from training by reducing the risk of LBP, as well as for clinical patients undergoing rehabilitation from LBP or low-back surgery. The purpose of this study was to evaluate the frequency of training on the development of lumbar extension strength. An additional purpose was to examine the specificity of isometric exercise training on low-back strength. Because we have been using a multiple joint angle isometric test to quantify lumbar extension strength through a 72° range-of-motion (ROM),[13,32] and this test is currently being used clinically to evaluate LBP patients, we were interested in determining the effect of repeated isometric testing on lumbar extension strength.

## METHODOLOGY

**Subjects.** Seventy-two men (age = 31 ± 9 years; height = 180 ± 6 cm; weight = 79.9 ± 11.4 kg) and 42 women (age = 28 ± years; height = 167 ± 7 cm; weight = 62.1 ± 10.1 kg) completed the testing and training required for this study. All subjects were sedentary volunteers who had no history of chronic LBP, heart disease, or any orthopaedic contraindication to exercise. The study was approved by the Institutional Review Board of the University of Florida College of Medicine, Gainesville, Florida. Written informed consent was obtained from each subject.

**Testing.** Before training, all subjects completed two isometric lumbar extension strength tests on separate days. The test days were separated by at least 72 hours to allow subjects ample time to recover from any residual fatigue or soreness that might have been associated

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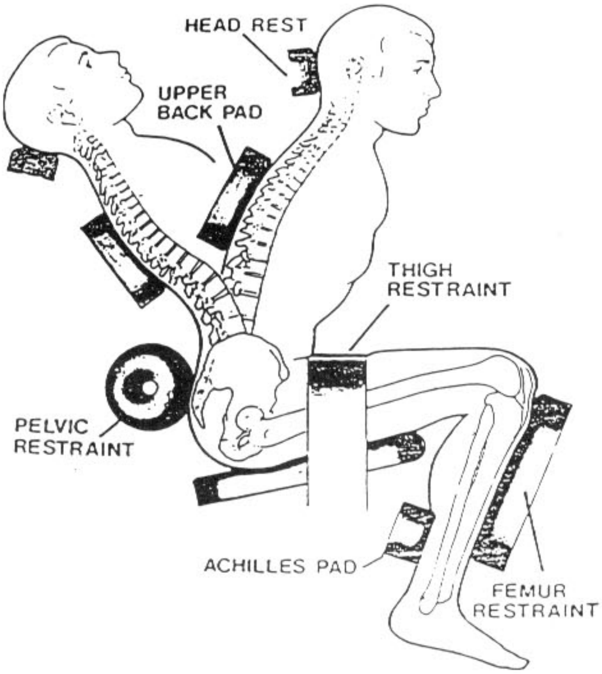


**Fig 1.** Restraining mechanisms of the MedX (Ocala, FL) lumbar extension machine.

with the testing. For each test, maximum voluntary isometric lumbar extension strength was measured with a MedX (Ocala, Florida) lumbar extension machine (Figure 1) at seven positions through a 72° ROM. The seven positions measured were 72°, 60°, 48°, 36°, 24°, 12°, and 0° of lumbar flexion. The testing positions were standardized by using an electronic goniometer interfaced to the microprocessor of the testing machine. Details regarding test standardization and evaluation of the test protocol have been reported by Graves et al.[13]

**Training.** After completion of the pretraining testing, the subjects were rank ordered by peak isometric strength and randomly stratified to one of five training groups or a control group that did not train. The five training groups differed in training frequency and type of training and included groups that trained dynamically once every two weeks (1×/2 weeks), once per week (1×/week), twice per week (2×/week), and three times per week (3×/week). In addition, one group trained isometrically one time per week (IM 1×/week). The characteristics of the subjects in each of these groups are presented in Table 1.

Training was conducted for 12 weeks. Upon reporting to the laboratory for each training session, subjects were seated and secured in the lumbar extension machine. For each training session, the subjects participating in dynamic training were required to perform one set of variable resistance lumbar extensions through a 72° ROM with a weight load that allowed 8 to 12 repetitions to volitional muscular fatigue. Each repetition was performed in a slow, controlled manner. The positive (concentric) portion of the lift was completed in 2 seconds, and after a brief pause (1 second), the negative (eccentric) portion of the lift was completed in 4 seconds. Progressive resistance exercise was achieved by increasing the weight by approximately 5% when 12 or more repetitions could be completed. The training weight and number of repetitions completed during each dynamic training session were recorded. The IM 1×/week group completed the seven-angle isometric lumbar extension strength test described previously during each training session. All training sessions were supervised by experienced laboratory personnel. After the 12 weeks of training, subjects were retested on two occasions. These posttraining tests were conducted following the same protocol used for the pretraining tests.

**Treatment of the Data.** The first pretraining test completed by the subjects was considered a practice test to familiarize the subjects with the testing machine and protocol. Previous research using the same test protocol has shown that after an initial practice session, subjects are able to give highly reliable ($r$ = 0.94 to 0.98) test results at all positions.[13] Therefore, the second pretraining test was used as the criterion measure of pretraining isometric strength. The posttraining isometric strength test yielding the highest strength values was used as the criterion test for posttraining strength. Isometric strength was measured in units of torque (N.m). Means and standard deviations were calculated for the pretraining and posttraining tests at each angle of measurement. Initial and final training weights were used as the criterion measures of pretraining and posttraining dynamic strength. Because pretraining strength differed among groups, the data were analyzed using an analysis of covariance (ANCOVA). The following preplanned comparisons were made: 1) changes in isometric strength for each group were compared with the control group; 2) changes in isometric strength and changes in training weight were compared among the four groups that trained dynamically; 3) isometric strength of the IM 1×/week group was compared with the group that trained dynamically one time per week. In all cases, pretraining criterion measures (isometric strength and training weight) were used as covariates. ANCOVAs were performed using the SAS[34] general linear model procedure. Statistical significance was accepted at $P < 0.05$.

## RESULTS

### Subjects

The 114 subjects who completed the study were part of an initial group of 170 volunteers (n = 106 men, n = 64 women) who began training. For various reasons, 41 subjects elected not to complete the 12 weeks of training. Five subjects experienced minor orthopaedic discomfort during the training program and could not continue training. These subjects were training two or three times per week and none of

Table 1. Characteristics of the Training and Control Groups

| | *Control* | | *1X/2wk* | | *1X/wk* | | *2X/wk* | | *3X/wk* | | *IM 1X/wk* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Variable* | *M* | *F* | *M* | *F* | *M* | *F* | *M* | *F* | *M* | *F* | *M* | *F* |
| N | 10 | 5 | 13 | 6 | 14 | 8 | 14 | 9 | 13 | 8 | 8 | 6 |
| Age (yr) | 29.8 | 27.6 | 30.8 | 29.2 | 32.4 | 25.0 | 34.8 | 35.3* | 32.5 | 28.9 | 27.4 | 24.8 |
| | ±10.2 | ±10.0 | ± 9.1 | ±11.9 | ± 7.4 | ± 4.5 | ±10.3 | ± 8.5 | ±12.3 | ±10.6 | ±10.2 | ± 4.4 |
| Height (cm) | 179.6 | 169.6 | 179.7 | 168.0 | 178.1 | 162.9 | 179.7 | 165.8 | 178.5 | 164.0 | 184.7† | 165.4 |
| | ± 5.0 | ± 6.4 | ± 8.0 | ± 3.8 | ± 6.3 | ± 5.6 | ± 4.3 | ± 5.3 | ± 5.3 | ±11.6 | ± 6.7 | ± 5.7 |
| Weight (kg) | 79.0 | 64.7 | 83.1 | 57.0 | 77.4 | 64.3 | 77.8 | 66.8 | 79.4 | 57.3 | 85.1 | 61.3 |
| | ± 8.7 | ± 9.4 | ±13.6 | ± 6.2 | ± 8.8 | ± 9.8 | ±10.5 | ±12.6 | ±12.4 | ± 9.1 | ±15.2 | ±10.6 |

Values are means ± SD.
*2X/wk > 1X/wk, IM 1X/wk, $P \leq 0.05$ (women only).
†IM 1X/wk > 1X/wk, 3X/wk, $P \leq 0.05$ (men only).

Table 2. Duration and Frequency of Training for the Dynamically Trained, Isometrically Trained, and Control Groups

| Group | N | Days Trained | Number of Workouts | Workouts Per Week |
|---|---|---|---|---|
| 1X/2wk | 19 | 79.6 ±15.4 | 6.2 ± 0.5 | 0.6 ± 0.1 |
| 1X/wk | 22 | 82.9 ±17.4 | 12.2 ± 2.2 | 1.0 ± 0.1 |
| 2X/wk | 23 | 84.3 ±17.1 | 21.9 ± 2.7 | 1.9 ± 0.4 |
| 3X/wk | 21 | 86.6 ±15.0 | 31.6 ± 5.5 | 2.6* ± 0.4 |
| IM 1X/wk | 14 | 74.9† ± 7.2 | 10.8 ± 0.6 | 1.0 ± 0.1 |
| Control | 15 | 87.1 ±22.2 | — | — |

*Significnatly less ($P \leq 0.05$) than the planned training frequency of 3 times per week.
†IM 1X/wk < 3X/wk, control ($P \leq 0.05$).

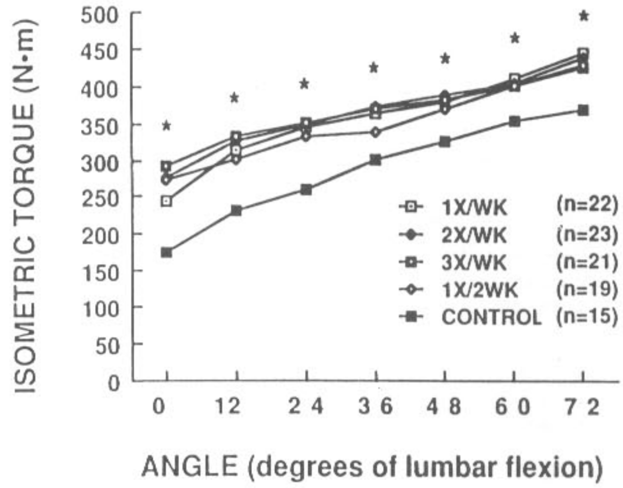


**Fig 2.** Adjusted posttraining isometric torques for the control group and the groups that trained dynamically every other week (1X/2wk), once per week (1X/wk), twice per week (2X/wk), and three times per week (3X/wk). * Control < 1X/2wk, 1X/wk, 2X/wk, 3X/wk ($P \leq 0.05$).

them required medical treatment. Ten subjects completed training but were unable to give a satisfactory effort during the isometric exercise testing and were excluded from analysis. These subjects were typically uncooperative individuals who tested with abnormal (nonlinear) strength curves that could not be reproduced on repeat testing. The actual training durations and frequencies for the 114 subjects who completed the study are presented by group in Table 2. Training durations ranged from 74.9 days (10.7 weeks) for IM 1×/week to 86.6 days (12.4 weeks for 3×/week. The control period was 87.1 days (12.4 weeks). The only group that did not attain the preplanned training frequency ($P < 0.05$) was the 3×/week group that averaged 2.6 workouts per week.

## Frequency of Training

Adjusted posttraining isometric torques for the control group and the four groups that trained with variable resistance dynamic exercise are presented in Figure 2. When compared with the control group, the groups that trained 1×/2 weeks, 1×/week, 2×/week, and 3×/week, all showed a significant ($P < 0.05$) improvement in the ability to generate isometric torque throughout the full ROM. When these training groups were compared among themselves, there were no statistical differences ($P > 0.05$) in the magnitude of the training responses. When the changes in isometric torque were expressed on a relative basis (Table 3), an 11.5 to 18.6% improvement was noted at the fully flexed position (72° of flexion) and a 53.7 to 129.7% improvement was noted at the most extended position (0° of flexion). There was no significant angle by treatment effect (training) interaction ($P > 0.05$), indicating that the shape (slope) of the strength curve did not change as a result of training.

Initial training weights and adjusted mean values for the amount of weight used during the final week of training are presented in Table 4. On the average, the dynamically trained groups were completing 11.2 to 11.8 repetitions during the final week of training. The group that trained 1×/2 weeks increased their training weight (26.6 ± 10.7%) to a lesser extent then the groups that trained 1×/week (38.9 ± 15.1%, $P = 0.08$), 2×/week (41.4 ± 17.3%, $P = 0.01$) and 3×/week (37.2 ± 19.0%, $P = 0.06$). There were no statistical differences ($P > 0.38$) when the groups that trained 1×/week, 2×/week, and 3×/week were compared with each other.

## Specificity of Training

Adjusted posttraining isometric torques for the 1×/week, IM 1×/week, and control groups are presented in Figure 3. Both 1×/week and

Table 3. Relative Changes in Isometric Torque (%)

| Group | N | Angle (degrees of flexion) 0 | 12 | 24 | 36 | 48 | 60 | 72 |
|---|---|---|---|---|---|---|---|---|
| 1X/2wk | (19) | 105.0 ±185.2 | 25.1 ±30.7 | 20.2 ±23.5 | 14.8 ±19.9 | 17.6 ±20.0 | 15.5 ±14.6 | 11.5 ±13.0 |
| 1X/wk | (22) | 53.7 ±51.6 | 35.9 ±33.2 | 29.7 ±29.4 | 25.1 ±28.0 | 20.7 ±22.1 | 20.6 ±20.9 | 18.6 ±19.4 |
| 2X/wk | (23) | 100.4 ±99.0 | 40.0 ±36.2 | 28.7 ±22.3 | 25.0 ±18.5 | 19.8 ±14.9 | 17.2 ±14.7 | 17.1 ±15.8 |
| 3X/wk | (21) | 129.7 ±141.1 | 48.4 ±36.1 | 35.8 ±29.7 | 30.0 ±24.1 | 23.8 ±24.6 | 21.8 ±25.7 | 15.7 ±21.4 |
| IM 1X/wk | (14) | 76.1 ±52.6 | 38.0 ±32.3 | 27.3 ±30.8 | 25.9 ±22.3 | 20.4 ±19.8 | 13.9 ±17.3 | 13.2 ±16.8 |
| Control | (15) | 7.7 ±32.3 | −0.9 ±17.6 | −0.6 ±20.4 | 7.2 ±23.4 | 7.8 ±20.6 | 4.9 ±15.9 | −1.3 ±12.0 |

Values are means ± SD.

Table 4. Initial and Adjusted Final Training Weights for the Groups that Trained 1X/2wk, 1X/wk, 2X/wk and 3X/wk

| Group | N | Initial training weight (kg)* | Adjusted final weight (kg)† | reps‡ |
|---|---|---|---|---|
| 1X/2wk | 19 | 74.2 ± 21.0 | 90.6‖ | 11.8 ± 3.2 |
| 1X/wk | 22 | 66.0 ± 19.4§ | 97.2 | 11.3 ± 1.5 |
| 2X/wk | 23 | 73.4 ± 24.2 | 100.3 | 11.7 ± 1.8 |
| 3X/wk | 21 | 73.0 ± 24.2 | 97.6 | 11.2 ± 1.6 |

*Values are means ± SD.
†Values are adjusted by analysis of covariance using the pretraining training weight as the covariate.
‡Reps = average number of repetitions completed during the final week of training.
§1X/wk < 1X/2wk, 2X/wk, 3X/wk ($P \leq 0.05$).
‖1X/2wk < 1X/wk ($P = 0.08$), 2X/wk ($P = 0.01$), 3X/wk ($P = 0.06$).

IM 1×/week training resulted in significant ($P < 0.05$) improvements in isometric torque at all angles measured. There was no statistical difference ($P > 0.05$) noted between the dynamic (1×/week) and isometric (IM 1×/week) groups at any point in the ROM. Relative increases in torque generated for IM 1×/week were 13.2% and 76.1% for flexion and extension, respectively (Table 3). Again, no significant angle by treatment interaction ($P > 0.05$) was found, indicating that the training did not influence the shape of the strength curve.

## DISCUSSION

The prescription of exercise is an art that is based on scientific principles. The art of exercise prescription involves the application of the scientific principles of exercise to the individual. Frequency of training is a primary consideration when prescribing exercise. Training too seldom will yield little or no benefit. Even if the overload stimulus achieved during each training session is sufficient, too much time between training sessions will allow detraining to occur. However, training too frequently may result in overtraining and an increased risk of injury as the muscles worked are not allowed enough time for recovery.

Braith et al[5] showed that training the knee extensors (quadriceps) three times per week was superior to training twice per week for up to 18 weeks of training. This was found to be true for both isometric and dynamic training responses. Similar results have been noted for a dynamic chest press exercise.[10] The results of the current study are somewhat different than those that have been found for training the quadriceps and chest muscles. For the lumbar extensors, training frequencies between once every 2 weeks and 3 times per week were all equally effective at improving isometric strength over 12 weeks of training. Training every other week was less effective than training one to three times per week in improving dynamic strength, however.

When isometric measures are used as criteria values to assess strength, peak isometric force or torque is generally employed. Peak torque for the lumbar extensors occurs in the fully flexed position (72° flexion). Although training frequencies of one to three times per week were all effective in improving isometric strength through a 72° ROM, the 11.5 to 18.6% improvement in peak isometric torque observed in the current study was considerably less than the 42% improvement reported by Pollock et al.[32] Our dynamic strength increases (26.6 to 41.4%) were also less than the 60.6% increase noted by Pollock et al.[32] Because the subjects studied by Pollock et al[32] were all experienced weight weight-lifters, they may have represented a more highly motivated sample than average sedentary persons. Previously trained muscles generally possess a reduced potential for improvement than do untrained muscles[8] and, therefore, one might expect lower responses from trained subjects. But, as discussed by Pollock et al,[32] unless the lumbar extensors are effectively isolated (through pelvic stabilization), they will not respond to training. Thus, the subjects participating in the study by Pollock et al[32] were experienced and highly motivated individuals with untrained lumbar extensors. This may explain the unusually large increases in lumbar extension strength noted in that study.

The magnitude of both the peak isometric and dynamic training responses observed in the current study are similar to those observed for other low-back training studies[4,9] and for training other muscle groups (See Fleck and Kraemer, 1987, for review). The full ROM training responses indicate that when variable resistance dynamic exercise is performed in a slow, controlled manner, this mode of training is effective for developing lumbar extension strength throughout the entire ROM. Although the shape of the lumbar extension strength curve did not change as a result of training, on a relative basis the isometric training effect noted in the fully extended position (53.7 to 129.7%) was greater than that for flexion (11.5 to 18.6%). These changes in strength are indicative of a general weakness throughout the ROM, which is most pronounced in the more extended positions. Whether continued training can effectively alter the shape of the lumbar extension strength curve remains to be determined.

Comparisons of strength gains between isometric and dynamic training generally follow a pattern of test specificity. That is, isometric training is superior to dynamic training when strength changes are evaluated isometrically, and, conversely, dynamic training is superior when dynamic testing is employed.[4] Isometric training responses in the current study were not related to the mode of training. Isometric and dynamic training one time per week resulted in similar improvements in isometric strength throughout the 72° ROM tested and indicate that multiple joint angle isometric training can be as effective as dynamic training for developing full ROM isometric lumbar extension strength. One viable explanation for the lack of specificity observed is the slow controlled manner in which dynamic exercise was performed. It has been suggested that exercise at slow speeds closely simulates isometric effort[31] and may influence training responses when testing isometrically.[25] Because a dynamic exercise test was not used in the current study to quantify dynamic strength, the effect of isometric training on dynamic lumbar extension strength could not be determined.

The improvement in lumbar extension strength after isometric training is an important finding that should be considered when individuals

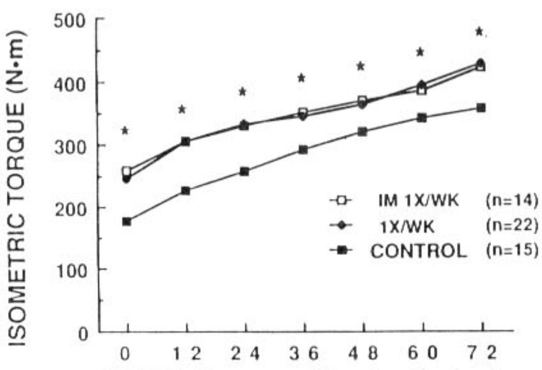


**Fig 3.** Adjusted posttraining isometric torques for the control group and the groups that trained isometrically one time per week (IM 1X/wk) and dynamically one time per week (1X/wk). * Control < IM 1X/wk, 1X/wk ($P \leq 0.05$).

are being evaluated periodically using a multiple position isometric exercise test protocol. It is evident that this protocol is sufficient to elicit a beneficial training response. Thus, the testing protocol may be effectively incorporated into a patient's training regimen. In addition, improvements in strength from the isometric testing procedure must be expected after periodic evaluation of patients or research subjects. Because a dynamic exercise test was not used in the current study to quantify dynamic strength, the effect of isometric training on dynamic lumbar extension strength could not be determined.

Although there were no statistical differences among the groups that trained one time per week, two times per week, and three times per week, for both isometric and dynamic strength, examination of the individual training responses within each of these groups showed that one individual could not tolerate a training frequency of three times per week. After an initial improvement in dynamic strength, this subject began to decline in the number of repetitions completed and the amount of weight used for training. It is likely that the recovery time between training sessions was not sufficient and this person was overtraining at a frequency of three times per week. A further indication that frequent high intensity low-back training may be contraindicated for some individuals is the fact that the subjects who experienced orthopaedic discomfort during training were individuals that trained more than one time per week. The discomfort noted occurred during training, not testing, and thus may be related to the recovery time allowed between exercise sessions. It was a common occurence for subjects training in the 3×/week group to complain of chronic fatigue. Whether the lumbar extensors can tolerate and benefit from greater training frequencies after 12 weeks and whether exercise intensity should be reduced once a certain level of functional strength is obtained are important questions that require further investigation.

Graves et al[11] present evidence that training intensity is an important factor with respect to the acquisition and maintenance of muscular strength. A training protocol involving one set of 8 to 12 repetitions to volitional muscular fatigue represents a low volume but high intensity method of training. Because this protocol requires less time than multiple set protocols, using one set to fatigue is a very efficient method of training. Training with one set to fatigue is currently popular in many training facilities and has been shown to be an effective method of training in several studies.[5,11,12,16] However, the number of injuries sustained during training (five) in a relatively short period of time (12 weeks of training) is disconcerting.

Because the lumbar extensors are rarely, if ever, isolated during normal daily activities, they seldom encounter an overload stimulus required to gain strength. Thus, they are are relatively weak muscles before training. Weak muscles may require relatively long recovery periods from high intensity training. Therefore, a training frequency of once per week may provide the safest and most effective frequency of training for the lumbar extensors, at least during the initial stages of training. Because training every other week was found to provide most of the strength gains noted for the other training frequencies, training 1×/2 weeks may be appropriate for clinical and preventive applications.

## SUMMARY

In conclusion, variable resistance exercise training at frequencies of one time every 2 weeks, one time per week, two times per week, and three times per week are all effective at improving isometric and dynamic strength of lumbar extensors during the first 12 weeks of training. These training responses were observed through the full range of lumbar extension. The one set of 8 to 12 repetitions to volitional fatigue completed during each training session resulted in 11.5 to 18.6% improvements in peak isometric torque (72° of flexion) and 53.7 to 129.7% in full extension (0° flexion). Improvements in dynamic strength were 26.6 to 41.4%. Training one time every 2 weeks was not as effective as more frequent training in improving dynamic strength. Due to the potential for overtraining associated with training two and three times per week, a training frequency of one time per week is recommended and may provide the safest and most effective frequency of training for the isolated lumbar extensors during the first 12 weeks of training. Isometric exercise testing is effective at increasing isometric strength of the lumbar extensors and should be considered when prescribing exercise and evaluating individuals in a clinical setting.

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