Frequency and Volume of Resistance Training: Effect on Cervical Extension Strength

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• Quantification of cervical extension (CERV EXT) strength is complicated by the inability to stabilize the torso and isolate the CERV EXT muscles. A newly developed machine designed to stabilize the torso and isolate the CERV EXT muscles was used to evaluate the effect of frequency and volume of resistance training on CERV EXT strength. Fifty men (age, 26 ± 9 years; height, 174 ± 16cm; weight, 74 ± 9kg) and 28 women (age, 30 ± 9 years; height, 152 ± 32cm; weight, 62 ± 7kg) volunteered to participate. Subjects were randomly stratified to one of four training groups or a control group (CONT, *n* = 19) that did not train. Each training group exercised for 12 weeks as follows; once per week using one set of dynamic exercise (DYN 1×/wk, n = 14), once per week using one set of DYN and one set of maximal isometric (IM) exercise at eight angles through a 126°-range of CERV EXT (DYN-IM 1×/wk, n = 16), DYN 2×/wk (n = 19), or DYN-IM 2×/wk (n = 10). Maximal IM torque was measured at eight angles initially and after 12 weeks of training. All training groups improved CERV EXT strength ($p \leq 0.05$) at all angles tested compared to the CONT except for DYN once per week at 0° of CERV flexion. A greater increase in strength was found when the groups that trained two times a week were compared to those that trained once per week. The results indicate that only a single set of CERV EXT exercise is required to attain a full range-of-motion increase in strength as long as the training frequency is at least two times per week.

Head and neck pain are common and costly concerns that plague a vast number of individuals in modern society.[1] Neck pain often originates from muscular weakness and fatigue, and from injuries associated with accidents and participation in athletics.[2-4] Neck injuries are especially prevalent in high impact activities such as football, wrestling, diving, and gymnastics.[5-10] Cervical spine injuries are caused by contact, overuse, twisting, compression, direct shearing forces, and alignment abnormalities.[1,11-13] Neck muscle strength has been shown to be a controlling factor in the stability of the cervical spine.[14] From this, it would seem appropriate to define safe and effective methods for strengthening the cervical muscles. The importance of strengthening the neck musculature to reduce the risk of injury, alleviate neck pain, and in rehabilitation has been well documented.[10-12,14-16] However, an effective method of strengthening the cervical extensor (CERV EXT) muscles through a full range of motion (ROM) has not been established.

Previous investigations of testing and training techniques for the muscles of the neck have been limited.[11,15,17-20] A machine designed to accurately evaluate and train the CERV EXT musculature was recently developed.[19] This machine was designed to satisfy four primary factors that are necessary for accurate and reliable assessment of CERV EXT strength: (1) isolation of the active musculature via torso stabilization; (2) measurement of full ROM CERV EXT strength; (3) compensation for the influence of gravitational forces acting on the head and neck; and (4) standardization of position and procedures. Leggett and colleagues[19] found the machine to be highly reliable when testing isometric (IM) CERV EXT strength on different days at eight angles through a 126°-ROM (r = 0.88 to 0.96 from 126° to 0° of CERV flexion). The researchers also reported significant increases in CERV EXT strength at six of eight angles evaluated (36° to 126° of CERV flexion) following ten weeks of training that was conducted one time per week (1×/wk) using a single set of dynamic (DYN) variable resistance exercise.[19] There was no significant increase in strength at 0° and 18° of CERV flexion. Greater frequency (2× or 3×/wk) and volume (multiple sets) of resistance training are generally recommended[21] and may provide a more effective training stimulus for the development of CERV EXT strength through a full ROM. Thus, the purpose of this study was to evaluate the effect of frequency and volume of training on CERV EXT strength. This information will aid clinicians in making recommendations for CERV EXT training.

METHODS

Subjects

Fifty men (age, 26 ± 9 years; height, 174 ± 16cm; weight, 74 ± 9kg) and 28 women (age, 30 ± 9 years; height, 152 ± 32cm; weight, 62 ± 7kg) completed the testing and train-

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ing protocol for this study. All subjects were volunteers from Gainesville, FL and the surrounding area and had no previous experience with CERV EXT exercise. Prior to testing, subjects completed medical history and physical activity profiles, which were reviewed for contraindications to resistance training exercise for the cervical spine. The study was approved by the Institutional Review Board of the University of Florida College of Medicine, Gainesville, FL, and each subject gave written informed consent.

Testing

All subjects completed two IM CERV EXT strength tests prior to training. A recovery period of 72 hours minimum was provided following test 1 to insure complete muscular recuperation prior to test 2. Isometric torque was measured at eight positions of CERV flexion through a 126° ROM (126°, 108°, 90°, 72°, 54°, 36°, 18°, and 0°) (fig 1) on a CERV EXT machine.[a] These angles of measure have been described previously by Leggett and coworkers[19] and Highland and associates.[21] Subjects were instructed not to exercise for at least 24 hours prior to testing. This testing protocol yields highly reliable results for all angles of CERV EXT.[19]

Upon reporting to the laboratory for testing, subjects were seated in the CERV EXT machine. The seat was adjusted so that the subject's thyroid cartilage was in alignment with the axis of rotation of the movement arm. Proper alignment allowed no sliding to occur between the head and the resistance pad during the CERV EXT exercise. Subjects were then secured in place by a specially designed restraint system that included a shoulder harness, seat belt, and torso restraint (fig 1). The shoulder harness prevented movement of the torso. The seat belt aided in a similar fashion by securing the pelvis in the seat. The torso restraint consisting of two pads mounted on an adjustable crank that were placed against the chest, below the clavicles, further stabilized the torso. Tightening the torso restraint forced the upper torso against the back of the seat. The combination of these restraining forces stabilized the torso, allowing no lateral, vertical, or rotational movement. Standardized positioning of the arms was achieved by instructing the subjects to maintain a light grasp on the anterior side of the torso restraint.[19]

After the torso was stabilized and the testing position standardized, the subject's head was moved into a neutral, upright posture (between 54° and 90° of CERV flexion). A counterweight was locked into place at this position and the subject's head was then moved to 18° of CERV flexion. The counterweight was adjusted while the subject's head rested against the resistance pad to neutralize the weight of the head. The position of the seat, angle of neutral posture, and counterbalance adjustment were recorded and used for all subsequent testing and training sessions.

To initiate a test, subjects were locked into position at 126° of CERV flexion and instructed to slowly and continuously extend their head against the resistance pad for a 2- to 3-second period. Once maximal torque had been produced, subjects were instructed to maintain the contraction for an additional 1 to 2 seconds and then relax slowly over a 2- to 3-second period. A 10-second rest interval was provided between each IM contraction while the next angle of measurement was set. Concurrent visual feedback was provided during each contraction on a video display screen that was interfaced to the machine. Subjects were verbally encouraged to exert maximal effort. To insure torso stabilization, the torso restraint was tightened if any torso movement was observed during testing.[19]

Training

Following pretraining testing, the subjects were rank ordered by peak IM torque and randomly stratified to one of

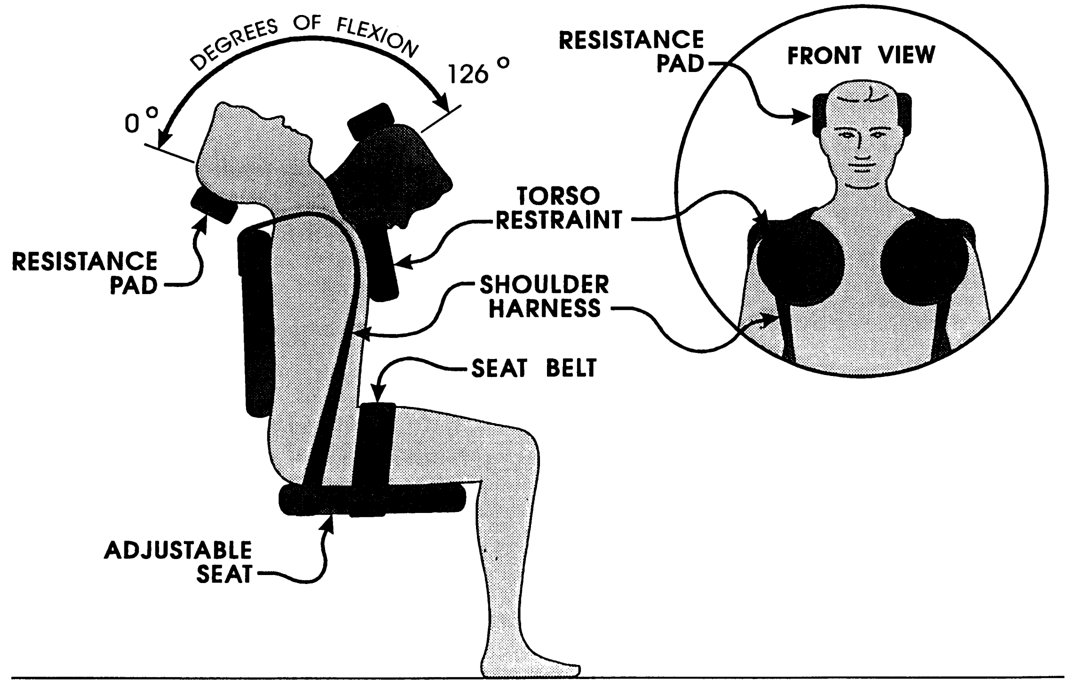

Fig 1—Range of motion and restraining mechanisms of the cervical extension machine, MedX.

four training groups, or a nontraining control (CONT, $n = 19$) group. Each training group exercised for 12 weeks as follows; once per week using one set of dynamic exercise (DYN 1×/wk, $n = 14$), once per week using one set of DYN exercise and one set of IM exercise at eight positions in the ROM (DYN-IM 1×/wk, $n = 16$), twice per week using one set of DYN exercise (DYN 2×/wk, $n = 19$), and twice per week using one set of DYN exercise and one set of IM exercise (DYN-IM 2×/wk, $n = 10$). Training sessions for the 2×/wk groups were separated by a minimum of 48 hours.

Prior to each training session, the subjects completed one warm-up set of DYN exercise. The resistance used in the warm-up was set at approximately 50% of the training load for DYN training, or 40% of the peak torque for IM training. DYN training consisted of one set of variable resistance CERV EXT exercise through a 126° ROM with a weight load that allowed eight to 12 repetitions to volitional muscular exhaustion. With emphasis on muscular control, each repetition of DYN exercise was performed with a 2-second concentric phase, a 1-second pause, followed by a 4-second eccentric phase. For the initial training session, the DYN weight load used for each subject was calculated from 80% of the peak IM torque produced in pretraining test 2. The weight load was increased by approximately 5% when a set of 12 repetitions or more was achieved.

The eight angle IM strength test described previously was used for IM training in the two DYN-IM groups. Subjects in these two groups began each session with IM training and were given a 5-minute rest period prior to DYN training. All training sessions were supervised by experienced laboratory personnel, who recorded total exercise time, training load, and the total number of repetitions completed. After 12 weeks of training, subjects were retested on two separate days, following the same procedures and protocol used for pretraining testing.

Data Analysis

In accordance with data on the reliability of testing CERV EXT strength,[19] pretraining test 1 served as a practice test used to familiarize the subjects with the testing procedure, whereas pretraining test 2 was used as the criterion measure of pretraining IM torque. Of the two posttraining tests, the test yielding the greatest torque values (N · m) was used to represent the posttraining criterion for IM strength.

Descriptive statistics (mean ± SD) were computed for the pretraining and posttraining IM torques of each training group at each of the eight angles tested. Initial (week 1) and final (week 12) training loads (killograms) were used as the criterion measures of pretraining and posttraining DYN strength. Among-group differences were analyzed by analysis of covariance, using the SAS[22] general linear models procedure. To evaluate the influence of training, the following preplanned comparisons were made: (1) changes in IM torque for each group were compared to the CONT; (2) to evaluate volume of training changes in IM torque were compared between the two DYN-only groups and the two DYN-IM groups; and (3) to evaluate frequency of training changes in IM, torque were compared between the two 1×/wk groups and the two 2×/wk groups. Pretraining IM torque measures were used as covariates. Interactions (effects) of time-(pretraining to posttraining) by-group (treatment), time-by-angle, and time-by-angle-by group were tested using repeated measures multivariate analysis of variance.[22] Statistical significance was accepted at a $p \leq 0.05$ level of confidence.

RESULTS

Descriptive characteristics of the subjects by group are presented in table 1. The DYN 2×/wk group was significantly older than all other groups ($p \leq 0.05$). Although there was a trend for the DYN 2×/wk and DYN-IM 2×/wk groups to be lighter in body weight and shorter in stature than the other groups, the differences were not statistically significant.

Pretraining and posttraining IM torque values for each angle of measurement for all groups are presented in table 2. Significant improvements in CERV EXT strength were found in all four training groups following the 12 weeks of training ($p \leq 0.05$). Time-by-group and time-by-angle interactions were both significant ($p \leq 0.01$). Figure 2 shows the adjusted posttraining IM torques for all groups. In comparison to the CONT group, maximal IM torque increased significantly through the full ROM in all training groups except for DYN 1×/wk at 0° of CERV flexion. Mean relative improvements in strength by group at each angle of measurement are given in table 2. Increases in maximal IM torque at full CERV flexion (126°) ranged from 13.0% to 42.1% among the four training groups, whereas strength gains at the most extended position (0° of CERV flexion) ranged from 6.0% to 20.5%. There was no significant time-by-angle-by group interaction ($p > 0.05$), indicating that the change in the slope of the strength curves were similar among training groups.

Covariance analysis showing the adjusted mean posttraining IM torques (covaried from pretraining test results) for 2×/wk and 1×/wk groups are presented in figure 3. Greater improvements in CERV EXT IM strength were noted throughout the ROM between 36° and 126° of CERV flexion in response to 2×/wk training. The difference was statistically significant at 126° of CERV flexion ($p \leq 0.01$). The data exhibit consistent full ROM training effects for both DYN and combined DYN-IM training. No significant differences ($p > 0.05$) in maximal IM torque were found between the DYN and combined DYN-IM groups following training (fig 4).

The initial and final training work loads for DYN training are shown in table 3. All four training groups exhibited marked improvement in DYN strength (mean increase of 40.4%). The greatest DYN strength gain was found in the DYN-IM 2×/wk group; however, the results were not statistically significant among groups ($p > 0.05$).

DISCUSSION

It is well established that resistance exercise is the most effective method available for improving muscular strength.[23-27] It is also known that the effectiveness of a strength-training program is dependent upon several fac-

Table 1: Descriptive Characteristics of the Subjects by Group (mean ± SD)

Variable	Control	DYN 1X/wk*	DYN-IM 1X/wk†	DYN 2X/wk‡	DYN-IM 2X/wk§
N, Male	14	10	11	11	4
Female	5	4	5	8	6
Age (yr)	28.7 ± 11.4	26.6 ± 5.3	26.7 ± 8.1	37.7 ± 9.5‖	27.6 ± 7.2
Height (cm)	175.1 ± 8.5	176.3 ± 9.6	174.6 ± 7.1	173.8 ± 11.5	171.1 ± 8.1
Weight (kg)	70.1 ± 12.8	73.5 ± 11.7	69.7 ± 11.4	68.8 ± 14.4	68.9 ± 17.8

* DYN 1X/wk = one set of Dynamic CERV EXT training performed one time per week.
† DYN-IM 1X/WK = one set of Dynamic and isometric CERV EXT training performed one time per week.
‡ DYN 2X/wk = one set of Dynamic CERV EXT training performed two times per week.
§ DYN-IM 2X/wk = one set of Dynamic and one set of isometric CERV EXT training performed two times per week.
‖ DYN 2X/wk > CONT, DYN 1X/wk, DYN-IM 1X/wk, DYN-IM 2X/wk, $p \leq 0.05$.

tors including frequency, volume, and mode of training. What constitutes an optimal balance of these factors in order to maximize strength gain, however, is controversial.

One common factor in effective strength training and rehabilitation programs is the inclusion of maximal or near maximal voluntary muscular contractions (MVC).[23,24] The number of repetitions at which MVC is reached during DYN exercise is a function of the weight load used. For example, a weight load that produces MVC on the eighth repetition is termed an 8 repetition maximum (8RM). The number of repetitions performed to MVC is an important consideration in designing a resistance training protocol.[28] The greatest strength gains appear to result from resistances yielding 4 to 10RM.[25,26] Increasing the number of repetitions (ie, 12 to 20RM) by decreasing resistance will favor increases in muscular endurance.[23]

Posturally active muscles, such as the CERV EXT, require an endurance as well as sufficient strength to maintain their proper function. Large strength gains have been found in the cervical muscles using 6RM[11] and 8 to 12RM training loads.[19] A training range of 8 to 12RM has been suggested for preventing injuries of the neck in wrestlers[10] and 6 to 10RM has been recommended for rehabilitation in response to cervical injury.[13] Graves and associates,[29] Pollock and coworkers,[30] and Risch and colleagues[31] found significant strength gains in the lumbar extensor muscles using 8 to 12RM. In the training study of Leggett,[19] it is important to note that some subjects experienced cervical discomfort when the RM load allowed less than eight repetitions. This may indicate that the cervical musculature may not be suited for low RM weight loads. Thus, as a result of these findings, an 8 to 12RM was used in the present study.

The optimal number of sets of an exercise used to develop muscular strength is unclear. Fleck and Kraemer[23] recommend performing one to two sets during the initial six to 12 training sessions and three to six sets thereafter. Some research has found multiple sets to induce greater strength gains than single sets,[32,33] but other studies have found little difference when single-set training protocols were compared to training with two or three sets.[34,35] Our laboratory has found significant gains in strength in response to one set of variable-resistance exercise performed

Table 2: Mean ± SD Isometric Torques (N · m) and Percent Changes Pretraining to Postraining

Group	0	Angle (degrees of cervical flexion) 18	36	54	72	90	108	126
CONT	(*n* = 19)							
Pre	29.0 ± 10.1	32.8 ± 9.7	33.5 ± 9.2	35.0 ± 9.6	36.8 ± 10.4	38.7 ± 10.9	40.0 ± 13.4	44.6 ± 17.9
Post	29.1 ± 10.4	31.8 ± 9.9	33.3 ± 9.6	35.2 ± 9.7	36.3 ± 11.0	38.3 ± 12.3	39.7 ± 14.9	43.6 ± 18.0
% change†	−0.3	−3.0	−0.6	0.6	−1.4	−1.0	−0.8	−2.2
DYN 1X/wk	(*n* = 14)							
Pre	29.8 ± 7.4	31.6 ± 6.0	32.3 ± 6.4	33.9 ± 7.1	35.9 ± 7.5	38.0 ± 7.2	40.3 ± 9.5	47.0 ± 14.3
Post	31.6 ± 5.7	35.3 ± 7.5	35.1 ± 6.0	37.1 ± 7.2	39.0 ± 8.0	42.6 ± 10.2	46.3 ± 13.0	53.1 ± 20.7
% change	6.0	11.7*	8.7*	9.4*	8.6*	12.1*	15.0*	8.7*
DYN-IM 1X/wk	(*n* = 16)							
Pre	29.2 ± 10.2	34.2 ± 11.3	37.0 ± 13.6	37.5 ± 14.0	37.9 ± 13.6	39.2 ± 14.4	39.7 ± 14.8	41.7 ± 17.3
Post	35.2 ± 11.5	39.3 ± 14.5	41.3 ± 15.8	41.8 ± 16.1	42.5 ± 14.9	43.2 ± 14.9	46.5 ± 17.6	51.3 ± 23.7
% change	20.5*	14.9*	11.6*	11.5*	12.1*	10.2*	17.1*	23.0*
DYN 2X/wk	(*n* = 19)							
Pre	25.6 ± 10.1	29.5 ± 11.7	30.0 ± 11.9	30.3 ± 11.7	30.7 ± 12.2	31.7 ± 13.1	32.4 ± 13.5	33.2 ± 14.1
Post	30.3 ± 9.3	35.3 ± 12.2	35.8 ± 12.7	35.5 ± 12.8	36.4 ± 12.7	38.3 ± 13.9	40.5 ± 14.7	44.1 ± 17.3
% change	18.4*	19.7*	19.3*	17.2*	18.6*	24.0*	25.0*	32.8*
DYN-IM 2X/wk	(*n* = 10)							
Pre	23.7 ± 13.0	25.7 ± 11.7	26.7 ± 12.3	27.9 ± 11.9	27.2 ± 11.9	27.2 ± 11.4	28.2 ± 11.6	30.9 ± 11.6
Post	27.5 ± 11.4	30.2 ± 11.5	31.1 ± 12.6	31.0 ± 12.7	32.3 ± 12.6	33.9 ± 14.0	37.3 ± 14.7	43.9 ± 16.9
% change	16.0*	17.5*	16.5*	11.1*	18.8*	24.6*	32.3*	42.1*

* Post > Pre, $p \leq 0.05$ within group analysis. Refer to figures 2-4 for among-group results.
† [(Post − Pre-training IM torque)/Pre] × 100.

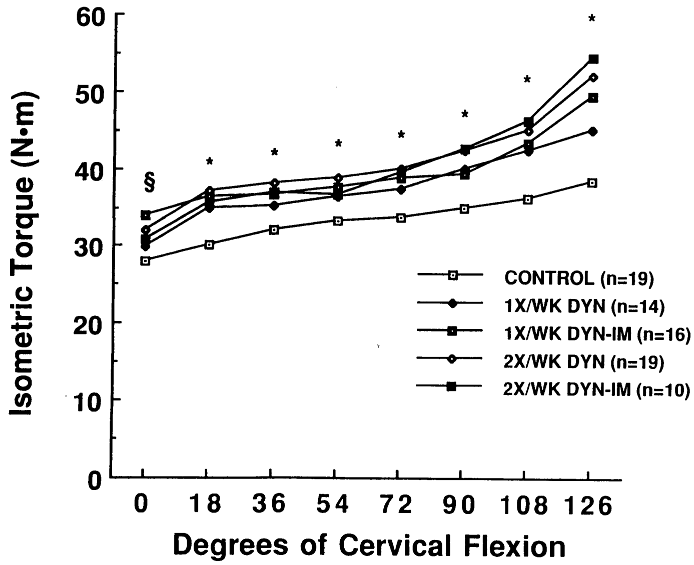

Fig 2—Covariance analysis adjusted posttraining IM torques for all groups. §1×/wk DYN-IM, 2×/wk DYN, 2×/wk DYN-IM > CONT,$p \leq 0.05$. *1×/wk DYN, 1×/wk DYN-IM, 2×/wk DYN, 2×/wk DYN-IM > CONT, $p \leq 0.05$.

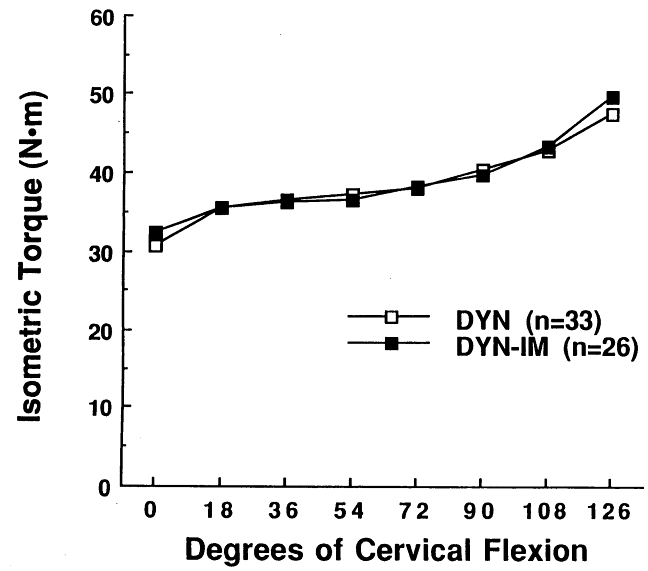

Fig 4—Covariance analysis adjusted posttraining torques for DYN versus DYN-IM training modes.

to volitional muscular fatigue.[19,29,30,31,36] In addition, Graves and colleagues[36] evaluated the importance of increasing volume of training by comparing one set with two sets of lumbar extension training conducted for a 12-week period. All sets were performed to volitional fatigue using 8 to 12RM. The res·ılts showed both groups to have similar improvements in full ROM IM torque. The results from the present study were in agreement with Leggett[19] in that only modest improvements in CERV EXT strength were attained from 36° to 120° of CERV flexion and no significant increase was found at 0° with one set of exercise performed 1×/wk. In the current protocol, the addition of a second set

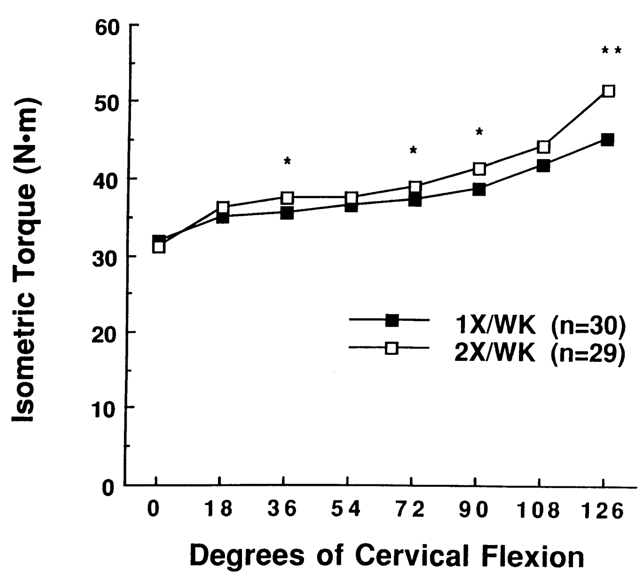

Fig 3—Covariance analysis adjusted posttraining IM torques for 1×/wk versus 2×/wk training frequencies. *2×/wk > 1×/wk, $p \leq 0.08$; **2×/wk > 1×/wk, $p \leq 0.01$.

(1×/wk DYN-IM) of CERV EXT exercise enhanced the training response and, most importantly, significantly increased IM torque through a full ROM.

As mentioned earlier, the frequency of training for a muscle group is an important component of a resistance training program.[25,28,37] The rest period must be sufficient allowing for muscular recuperation to prevent overtraining. Conversely, too much rest between training sessions can result in detraining. The optimal frequency of training is specific to the muscle group being exercised. Braith and colleagues[36] found 3×/wk to be superior to 2×/wk in increasing quadriceps (knee extension) strength. In comparing increases in lumbar extension strength, Graves[29] found no significant differences among groups training 1×/wk, 2×/wk, and 3×/wk. Leggett[19] showed modest strength improvement for the CERV EXT muscles with DYN training 1×/wk, (6.3% to 14.3% from 36° to 126° ROM). They found no significant gains in IM torque at 0° and 18° of CERV flexion.

The present study showed similar modest improvements in CERV EXT strength in response to training 1×/wk and the training stimulus was not sufficient to provide a full ROM effect. The current results indicate that training 2×/wk is superior to 1×/wk for increasing full ROM CERV EXT strength. The greatest gains in IM torque were found

Table 3: Initial Versus Final Dynamic Training Loads (kg) and Relative (%) Change

Variable	DYN 1X/wk	DYN-IM 1X/wk	DYN 2X/wk	DYN-IM 2X/wk
n	14	16	19	10
Initial	28.3 ± 6.7	28.1 ± 10.0	27.4 ± 8.5	25.3 ± 8.6
Final	38.2 ± 7.8*	39.9 ± 11.6*	38.2 ± 10.9*	36.3 ± 12.2*
% increase	35.0	42.0	40.9	43.5

Values are means ± SD.
* Final > initial, $p \leq 0.05$ within-group analysis.

in the DYN 2×/wk and DYN-IM 2×/wk groups, averaging 21.9% and 22.4% improvement, respectively, through a full 126° ROM. Less improvement was seen in response to 1×/wk training, with DYN 1×/wk and DYN-IM 1×/wk groups averaging 10.0% and 15.1% gains in IM torque, respectively, across the eight angles. Whether a greater frequency of training would give added improvement is not known.

Because there was not an IM-only training group in the current study, an exact comparison between IM and DYN modes of training could not be made. However, DYN and DYN-IM training in the present study showed similar improvement in IM torque through the full ROM (fig 4). No significant differences in posttraining maximal IM torque were found between the DYN and combined DYN-IM groups. The DYN-IM 1×/wk and DYN-IM 2×/wk groups also showed similar increases in DYN training resistance, improving 42.0% and 43.5%, respectively (table 3).

These results were not surprising because Graves[29] found no significant differences in gains of maximal IM torque between groups that trained the lumbar extensor muscles isometrically or dynamically using variable resistance exercise. The IM group trained at seven angles through a 72° ROM. More recently, Graves and associate[37] compared IM and DYN exercise only or in combination using full ROM lumbar extension training. The results were in agreement with the previous study[29] in that multiple joint angle IM exercise and DYN variable resistance training showed a similar full ROM effect. These results are in agreement with Knapiks and colleagues'[39] finding that IM exercise training at one specific angle increases muscular strength at positions up to 20° from the angle being trained.

The notion of using a set of multiple joint angle IM training to augment full ROM DYN exercise as a means of increasing training volume is not new. Teitz and coworkers[1] emphasized the importance of including a combination of IM and variable resistance isotonic exercise in strength training regimens to insure adequate development of muscular strength and endurance. More research is necessary to elucidate whether concurrent variable resistance DYN CERV EXT exercise and full ROM IM exercise provides a greater stimulus for strength gain than two sets of DYN CERV EXT exercise.

In summary, these results confirm our previous findings[19] that one set of DYN CERV EXT exercise 1×/wk is not sufficient to elicit a full ROM training effect. Full ROM strength benefits were found by training with two sets 1×/wk or one or two sets 2×/wk of CERV EXT exercise. Overall, more frequent training (2×/wk) induced a more favorable training response and insured a full ROM training effect. Because there was no significant difference in strength development when training 2×/wk between the one-set or two-set groups when exercising to volitional fatigue, including the additional set does not appear necessary. Combined multiple angle IM and DYN variable resistance training was effective for improving full ROM CERV EXT strength. Whether or not increased frequency or volume of training would further enhance the development of full ROM CERV EXT strength requires further study.

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