

■ Changes in Isometric Strength and Range of Motion of the Isolated Cervical Spine After Eight Weeks of Clinical Rehabilitation

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There have been no reports in the literature objectively measuring changes in strength and range of motion in patients with non-spinal-cord injuries of the cervical spine. Ninety patients participated in an 8-week training study. Diagnostic groups included patients with the following: degenerative disc ($n = 6$), herniated disc ($n = 14$), and cervical strain ($n = 70$). Full-range isometric strength tests were performed at eight equidistant positions in a device that constrained all motion with the exception of cervical flexion and extension. Post tests were performed following training. Significant gains were seen in strength as well as range of motion. Perceived pain was significantly reduced. This kind of testing can potentially provide the clinician with objective findings to direct patient management more adequately. [Key words: cervical spine, spondylosis, isometric strength tests, training effects]

Clinical assessment of the cervical spine has attracted interest in the literature as early as the late 1950s.² The variety of articles on this topic, however, have been principally concerned with biomechanical properties of cervical motion.^{1,4,5} Quantitative assessment of extensor strength, range of motion (ROM), and strength training in clinical populations have not been reported previously. One recent reliability study has provided the only known data regarding extensor strength and ROM in healthy subjects.³

There have been two primary reasons for this paucity of data. One has been a lack of instrumentation available to provide valid and reliable assessment of extensor strength capacity of the cervical spine. The second (possibly preventing the development of such instrumentation) has been the previously held feeling among clinicians that strength testing and training of the non-cord-injured cervical spine could be dangerous, further aggravating the injury.

Clinical instrumentation is now available that can provide reproducible quantitative assessment of both

extensor strength and ROM in the sagittal plane. It is also possible to prescribe very specific exercise training to cervical extensor muscles. The purpose of this study, therefore, was threefold:

1. To measure the strength and ROM in patients with non-spinal-cord injuries of the cervical spine;
2. To strength train these patients in an 8-week clinical rehabilitation program;
3. To determine whether this kind of testing and training is safe in clinical populations.

■ Methods

Ninety patients (39 male, 51 female) participated in an 8-week strength testing and training study at the Columbia Spine Center. Diagnostic groups included patients with the following: degenerative disc ($n = 6$), herniated disc ($n = 14$), and cervical strain ($n = 70$).

Before the strength assessment, all patients were evaluated by orthopaedic surgeons or nonsurgical conservative care physicians, and diagnoses were made. Appropriate clinical studies were performed to aid in diagnosis before patients were involved in the study.

Testing and training was performed in a MedX Cervical Extension Machine (MedX Corp., Ocala, FL). Patients were restrained via seat belt, shoulder harness, and torso restraint to prevent any additive strength effect from trunk musculature during the testing procedure (Figure 1).

The seat of the system was adjusted up or down in order for the resistance (head) pad to be at the appropriate height. Range of motion was measured by asking each patient to extend his or her head backward as far as possible. Each patient was then asked to flex his or her neck forward as far as possible (the range of the machine is 126°). These measures were recorded. While in the extended position, the head was weighed and counterbalanced so as to negate the effects of gravity during the testing and training protocols. This was important because the effect of gravity would overstate the patient's strength in the extended position and understate strength in the flexed position.

While restrained in the device, and beginning in the flexed position, the patients performed isometric contractions (toward extension) throughout their full ROM at eight equidistant positions. The testing provided a strength curve, which then

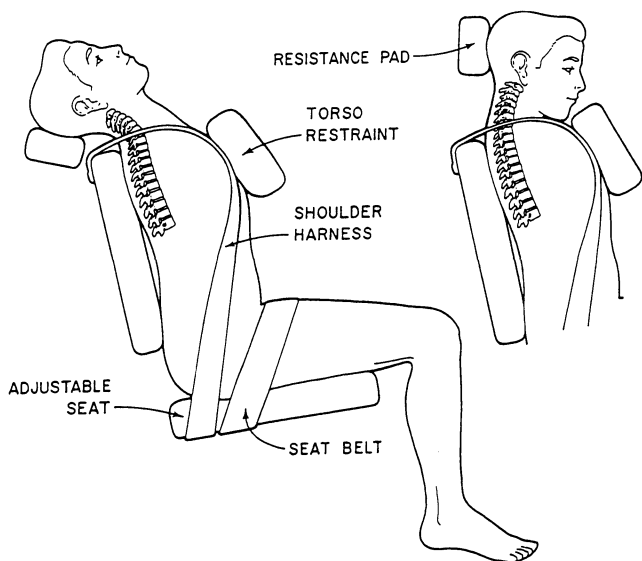


Figure 1. The patient is held in a seated position by a seat belt, shoulder harness, and torso restraint. This system eliminates contribution of trunk musculature in the measurement of cervical extensor strength.

was used to prescribe a dynamic exercise program to be performed in the same machine (Figure 2). To avoid poor result from a "naive" patient, each patient was oriented and exercised in the machine three times before the actual recorded pretest.

- *First visit:* Patients performed some stretching exercises before they got on the machine. They then performed very low-level dynamic exercise (13.56 Nm for men and 10.17 Nm for women), followed by an isometric strength evaluation.
- *Second visit:* Patients received a dynamic exercise session based on 80% of the maximal isometric torque from the initial evaluation. They were asked to perform as many repetitions as possible (up to 20). If 20 repetitions were achieved, the training weight was increased by 3.39 Nm during the next visit.
- *Third visit:* Another dynamic exercise session was performed based on the second visit.
- *Fourth visit:* Patients performed the pretest.

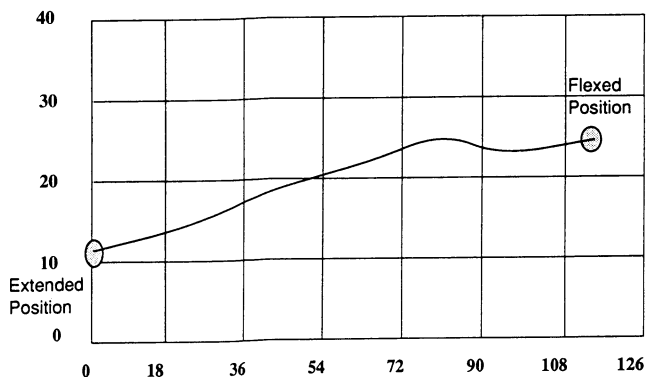


Figure 2. Strength curve obtained throughout a patient's ROM. Extension strength in the flexed position is to the right and extension strength in the extended position is to the left.

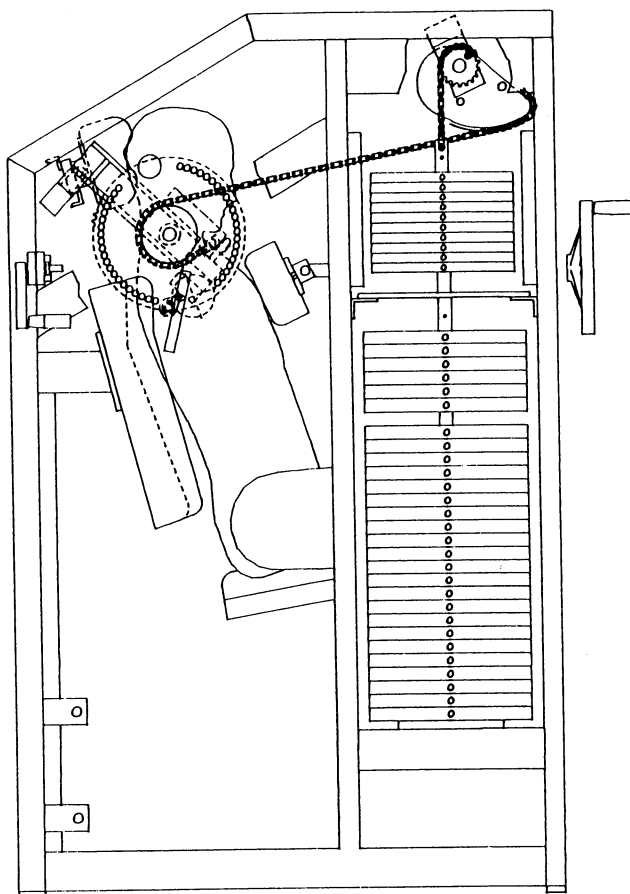


Figure 3. Dynamic variable resistance mechanism from a lateral view. The neck contracts concentrically (positive work) during extension and eccentrically (negative work) during flexion, causing the weight stack to move up and down.

After the testing session, patients were asked to respond to the amount of pain they were experiencing on a 10-point analog scale: 0 = no pain; 10 = maximal pain.

The cervical extension machine was used as a variable resistance device to provide dynamic strength training (Figure 3). Training consisted of two sessions per week for 4 weeks and one training session per week for the subsequent 4 weeks. The

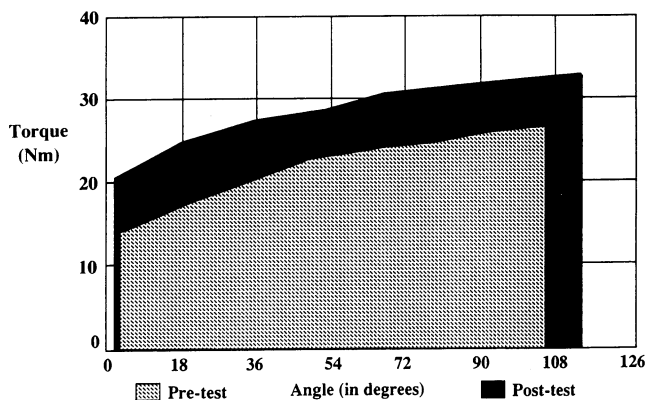


Figure 4. All patients grouped from the pretest and post-test. It can be easily seen that both gains in strength (y-axis) and ROM (x-axis) were made during the 8-week period.

Table 1. Summary Data for Range of Motion, Strength, and Patient Perception

	ROM (degrees) ^o	Flexed Strength (Nm)	Extended Strength (Nm)	Average Strength (Nm)	Pain (10 pt. scale)*	Helped (10 pt. scale)*
	Pre Post	Pre Post	Pre Post	Pre Post	Pre Post	
All patients (n = 90)	104 ± 16 113 ± 12†	30.5 ± 16.5 36.5 ± 15.8†	16.5 ± 10.5 21.6 ± 11.5†	25.6 ± 13.3 31.3 ± 13.7†	7.5 ± 2.2 3.2 ± 2.4†	6.7 ± 2.5
Sex						
Female (n = 51)	105 ± 15 115 ± 11†	21.6 ± 8.8 27.8 ± 10.5†	12.7 ± 6.9 18.9 ± 8.5†	18.3 ± 7.6 24.4 ± 9.0†	7.7 ± 2.1 3.1 ± 2.5†	7.3 ± 2.8
Male (n = 49)	103 ± 17 110 ± 12†	42.1 ± 17.1 47.35 ± 14.6†	21.4 ± 12.3 24.75 ± 14†	35.1 ± 13.3 39.78 ± 13.7†	7.1 ± 2.3 3.4 ± 2.3†	6.0 ± 1.9
Diagnosis						
Herniated Disc (n = 14)	104 ± 15 112 ± 14	29.8 ± 13.1 37.9 ± 14.2†	18.2 ± 9.5 22.5 ± 11.3	26.3 ± 11.1 32.3 ± 12†	6.7 ± 2.0 4.2 ± 3.2†	6.5 ± 3.3
Degenerated Disc (n = 6)	98 ± 14 112 ± 6‡	26.1 ± 9.9 32.5 ± 11.6‡	14.1 ± 10.7 14.2 ± 9.4	21.1 ± 11.3 25.8 ± 11.9†	9.0 ± 1.0 4.2 ± 2.7†	6.2 ± 2.0
Cervical Strain (70)	105 ± 16 113 ± 12†	31.0 ± 17.5 36.7 ± 16.6†	16.4 ± 22.6 22.1 ± 11.7†	25.9 ± 14 31.6 ± 14.1†	7.5 ± 2.3 2.9 ± 2.2†	6.8 ± 2.4
Type of Payment						
Worker's Compensation (n = 25)	101 ± 17 109 ± 13†	35.9 ± 19.5 41.9 ± 18.1	19.2 ± 12.5 23.5 ± 15.1‡	25.9 ± 15.1 35.4 ± 16.6‡	6.9 ± 2.7 3.8 ± 2.6†	6.3 ± 2.1
Private pay (n = 11)	108 ± 13 114 ± 10	34.0 ± 13.9 42.5 ± 14.2†	18.4 ± 8.7 22.1 ± 9.9†	28.1 ± 9.1 34.2 ± 9.5†	6.8 ± 2.0 3.7 ± 2.4†	6.3 ± 2.8
Legal (n = 54)	105 ± 16 115 ± 11‡	27.2 ± 14.8 32.4 ± 14†	14.8 ± 9.7 20.4 ± 9.9†	23.0 ± 12.8 28.5 ± 12.4†	7.9 ± 1.9 2.9 ± 2.3†	7.0 ± 2.6
Return to Work						
Work (n = 61)	105 ± 14 113 ± 11†	33.0 ± 17.3 38.8 ± 15.7†	17.2 ± 11.4 21.5 ± 11.6†	27.3 ± 14.1 32.9 ± 13.4†	7.5 ± 2.2 2.9 ± 1.9†	6.7 ± 2.4
Nonwork (n = 14)	89 ± 17 104 ± 14‡	21.13 ± 10.2 27.01 ± 11	13.7 ± 6.3 18.4 ± 10.8	18.76 ± 8.6 24.1 ± 11	6.8 ± 2.3 5.3 ± 2.6	5.7 ± 2.7

*10-point analog scale reflecting patient perception of how much the training program helped them (0 = no pain; 10 = maximal pain).

† = $P < 0.01$.

‡ = $P < 0.05$.

dynamic exercise load was set to reflect 80% of the measured maximal isometric strength of the pretest. The intent of the dynamic exercise was to get patients to reach momentary muscular failure. When they were able to perform the required number of repetitions (depending on the pretest), the weight was increased by 3.39 Nm. At the end of 8 weeks, the testing procedure was repeated.

At the completion of the project, patients were asked whether they thought the cervical training had been helpful to them. A 10-point analog scale was used: 0 = no help; 10 = extremely helpful.

Statistical analysis was performed using the Student *t* test for two-group paired data and multivariate analysis.

■ Results

Strength and Range of Motion

When all the patients were considered as a group, significant gains in strength were seen in all positions—extended, flexed, and average strength. Significant gains were also noted in ROM (Figure 4). Table 1 summarizes the data.

Subgroups were then analyzed according to sex, diagnosis, type of insurance payment, and whether or not the patients returned to work.

Both male and female subgroups showed significant gains in both strength and ROM (Figure 5). All of the diagnostic groups produced significant gains in average

strength, whereas only degenerative discs and cervical strain had significant gains in ROM (Figure 6). When considering type of insurance as a variable, all groups showed significant gains in average strength, whereas only Worker's Compensation and legal patients (patients who have retained the services of an attorney in their case) significantly gained in ROM (Figure 7). Seventy-five patients were working before cervical rehabilitation. Sixty-one (81%) of these 75 patients returned to work. In the return-to-work group, significant gains were seen in ROM and strength. In the patients who did not return to work, significant gains were seen only in ROM (Figure 8). The remaining 15 patients were students ($n = 9$), disabled ($n = 2$), and patients whose status was unknown ($n = 4$).

Pain Perception and Patient Satisfaction

All patients as a group showed significant reduction in their perception of pain as a result of the training program. All subgroups also, with the exception of the patients who did not return to work, showed significant reduction in perceived pain.

The majority of patients thought that the strength training program had helped them considerably, patients who did not return to work perceiving the least degree of help.

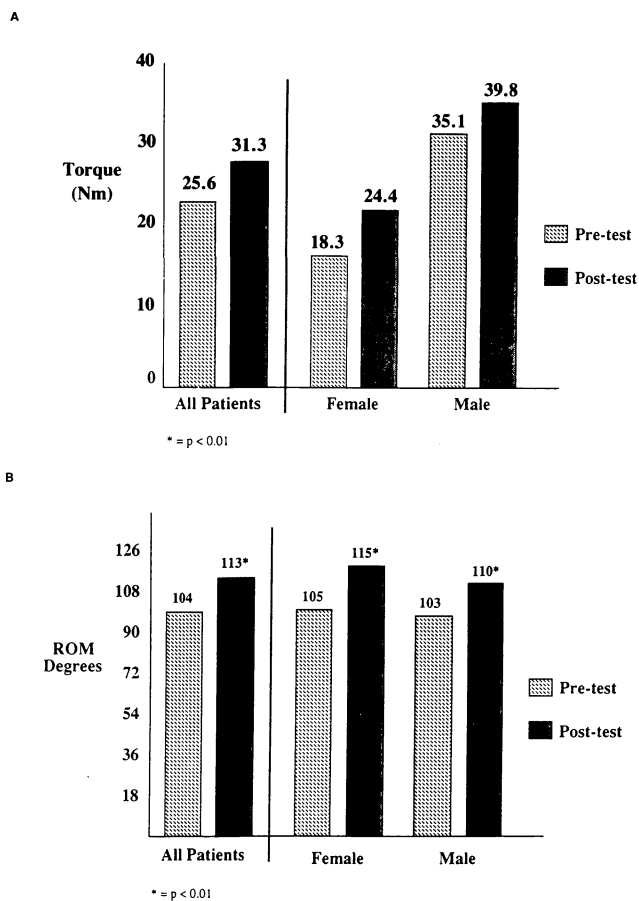


Figure 5. **A**, Changes in average strength by female and male subgroups. **B**, Changes in ROM by female and male subgroups.

An important question during this study was the safety of this approach to rehabilitation of the cervical spine. None of our patients was injured during the training period. We therefore believe this program is clinically safe.

Discussion

Previous reports of strength and ROM of the cervical spine in clinical populations have not appeared in the literature. This is an important area of investigation because little is known about the dynamics of the injured cervical spine *in vivo*. A major obstacle to performing this kind of study has been a lack of instrumentation as well as concern about the safety of this aggressive an approach.

In this particular population, we were able to measure strength and ROM safely, train, and reevaluate our patients with cervical spine injuries.

Significant gains in average strength were seen in all groups with the exception of the patients who did not return to work. Although this group was much weaker, their absolute strength gains were similar to those of the

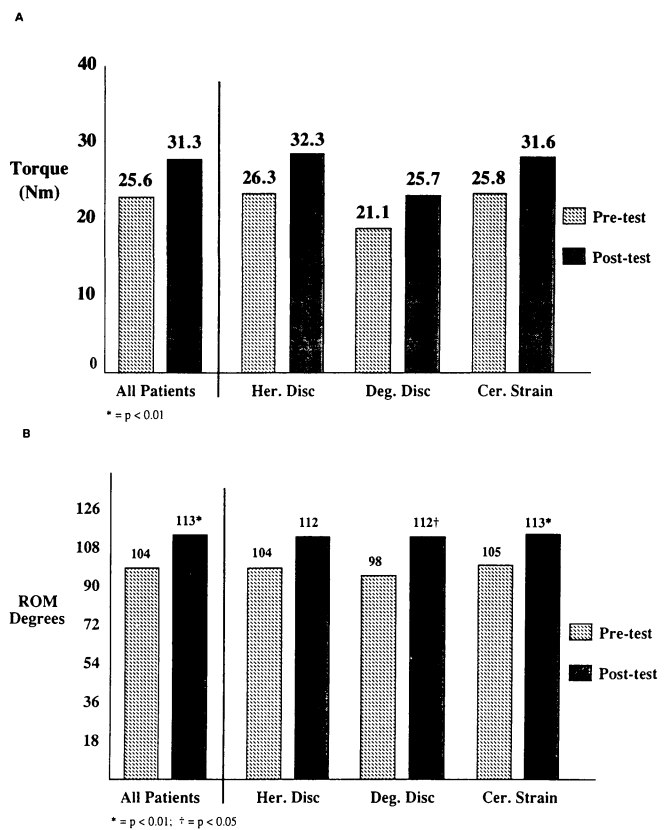


Figure 6. **A**, Changes in average strength by diagnosis. **B**, Changes in ROM by diagnosis.

group that returned to work. Lack of significant change in the nonworking group ($P < .08$) was probably due to the small number of patients in this group ($n = 14$). Had the subgroup been a little larger, we would have expected to see significant change. We were not able to perform subgroup interactive analysis because the numbers among groups were too uneven.

Range of motion gains were significant in all groups with the exception of the herniated discs group ($P < .08$) and the private pay group ($P < .09$). Again, the lack of statistical significance was probably due to the small numbers in the two subgroups (herniated disc: $n = 14$; private pay: $n = 11$).

It was also interesting to note that all of the subgroups, with the exception of the group that did not return to work, showed significant reduction in pain. The lack of statistically significant pain reduction in the patients who did not return to work seemed to be represented by their lower initial and post-test average strength and ROM than those of any of the other subgroups.

As a reflection of patient satisfaction, the patients were asked to indicate whether they felt the MedX Cervical Extension Machine was helpful to them. As with

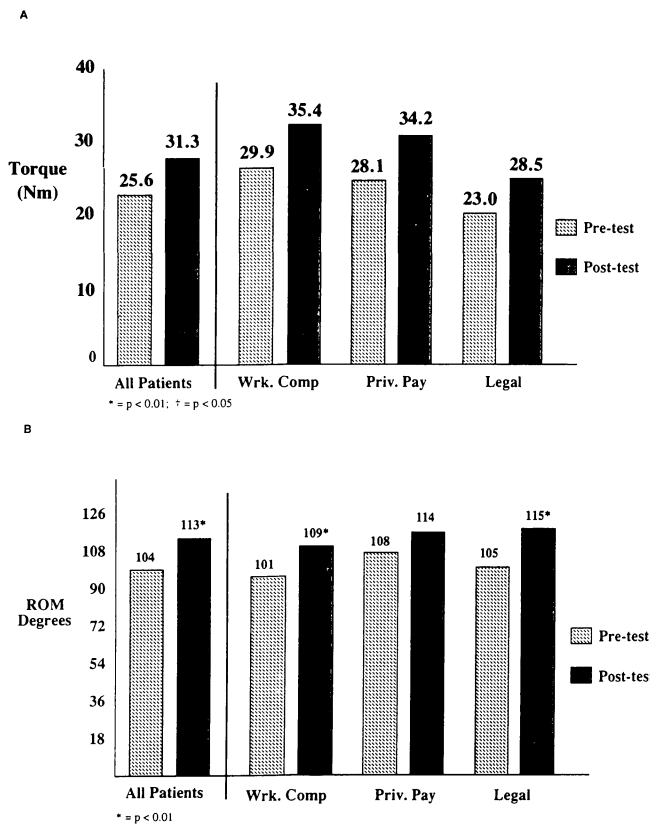


Figure 7. **A**, Changes in average strength by type of insurance. **B**, Changes in ROM by type of insurance.

strength and ROM, the patients who did not return to work perceived the least degree of help from this treatment.

Because this is a new approach to rehabilitation of non-cord-involved cervical injuries, there is very little to which we can compare it. The only other study available to us was performed on healthy individuals by Leggett et al at the University of Florida.³ They showed that the instrumentation (MedX Cervical Extension Machine) used in our study is valid and reliable.

There are some observations, however, that can be made. We now have a tool that we believe can safely and reproducibly provide clinically quantitative extensor strength information on patients with non-spinal-cord injuries of the cervical spine. It is of further interest that increases in extensor strength over time seem to reflect our clinical impressions regarding patient recovery. In other words, as the patients got stronger, they seemed better clinically.

We also now have a tool that, because of good isolation of the cervical spine, can provide reliable extension and flexion ROM. This is because the patients are firmly positioned precisely the same way each time they are tested. This increases confidence levels regarding consistent measures from test to test.

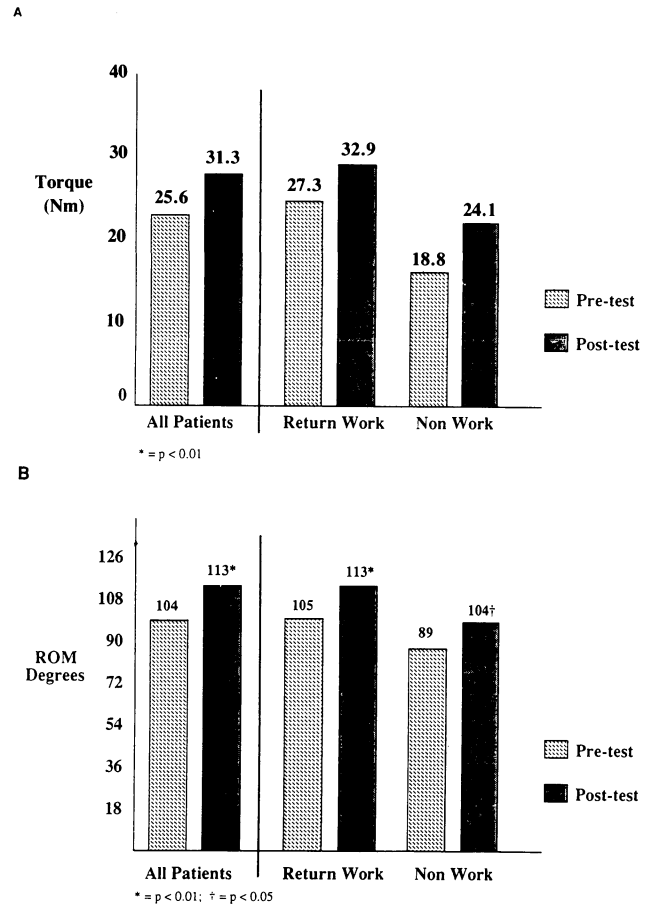


Figure 8. **A**, Changes in average strength by whether or not patients returned to work. **B**, Changes in ROM by whether or not patients returned to work.

In summary, 1) all groups showed significant gains in average strength and ROM; 2) all groups reported a decrease in perceived pain (with the exception of the patients who did not return to work); and 3) testing and training of the isolated cervical spine muscles is a safe and viable method of clinical assessment and treatment of a variety of cervical spine disorders.

We conclude that we now have a safe, valid, and reliable tool with which to measure changes in both strength and ROM in patients with non-spinal-cord injuries of the cervical spine. We believe that, in the right hands, this approach to rehabilitation can provide the clinician with important and timely data regarding patient progress.

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