The Effect of Early Isolated Lumbar Extension Exercise Program for Patients with Herniated Disc Undergoing Lumbar Discectomy

Gun Choi, M.D., Ph.D.
Wooridul Spine Hospital,
Seoul, South Korea

Pradyumna Pai Raiturker, M.D.
Wooridul Spine Hospital,
Seoul, South Korea

Myung-Joon Kim, M.S., P.T.
Wooridul Spine Hospital,
Seoul, South Korea

Chung Dai Jin, M.D.
Wooridul Spine Hospital,
Seoul, South Korea

Yu-Sik Chae, M.D.
Wooridul Spine Hospital,
Seoul, South Korea

Sang-Ho Lee, M.D., Ph.D.
Wooridul Spine Hospital,
Seoul, South Korea

Reprint requests:
Gun Choi, M.D., Ph.D.,
Wooridul Spine Hospital,
Chungdam-Dong 47-4,
Kangnam-Gu, Seoul, Korea.
Email: choigun@wooridul.co.kr

Received, August 26, 2004.
Accepted, June 21, 2005.

OBJECTIVE: To determine the effects of a postoperative early isolated lumbar extension muscle-strengthening program on pain, disability, return to work, and power of back muscle after operation for herniated lumbar disc.

METHODS: Seventy-five patients were randomized into an exercise group (20 men, 15 women) and a control group (18 men, 22 women) to perform a prospective controlled trial of a lumbar extension exercise program in patients who underwent lumbar microdiscectomy or percutaneous endoscopic discectomy. Six weeks after surgery, patients in the exercise group undertook a 12-week lumbar extension exercise program. The assessment included measures of lumbar extensor power by the MedX (Ocala, FL) lumbar extension machine, muscle mass of multifidus and longissimus (L4–L5 cross-sectional area) by computed tomography. All patients completed the visual analog scale and the Oswestry disability index to assess pain and disability, respectively. Return to work data were also investigated.

RESULTS: After the exercise program, significant improvements were observed in the exercise group versus the control group for lumbar extensor power (51.67% versus 17.55%, respectively; $P < 0.05$), the cross-sectional area of multifidus and longissimus muscle (29.23% versus 7.2%, respectively; $P < 0.05$), and the visual analog scale score (2.51 versus 4.30, respectively; $P < 0.05$). The percentages of returning to work within 4 months after surgery were significantly greater in the exercise group than in the control group (87% versus 24%, respectively). Although this was not statistically significant ($P > 0.05$), the Oswestry disability index scores in the exercise group were better than that in control group (24.6 versus 30.6, respectively).

CONCLUSION: These results support the positive effects of the postoperative early lumbar extension muscle-strengthening program on pain, return to work, and strength of back muscles in patients after operation of herniated lumbar disc.

KEY WORDS: Computed tomography cross-sectional area of multifidus and longissimus, Lumbar disc herniation, Lumbar extensor muscle exercises, Lumbar extensor muscle power

Neurosurgery 57:764-772, 2005 DOI: 10.1227/01.NEU.0000175858.80925.38 www.neurosurgery-online.com

Lumbar discectomy for prolapsed intervertebral disc is one of the most dramatic operations with gratifying results. With the progress made by science in the pathophysiology of disc herniations and imaging technologies and also the availability of various new treatment methods, the management of prolapsed intervertebral disc has been revolutionized. Still with so many new developments, the outcome of operations for disc herniations has not been 100%, and many patients still do not have satisfactory outcomes and continue to have some persisting symptoms. Approximately 80% of the patients return to work 12 months after surgery (34), whereas the remaining 20% do not. The reasons are varied and include the selection of patients, psychosocial aspects, and the variability in the spectrum of degenerative disc disease. But postoperative rehabilitation also has a considerable influence on the surgical results. A lumbar extension exercise program can be beneficial for strengthening the lumbar extensors and thus may improve the outcome in such patients. The objective of this study was to determine the effects of a lumbar extension exercise program on pain, disability, return to work, and power of the back muscle after lumbar discectomy. This is the first such study to provide objective, quantitative data and analysis of lumbar extensor muscle mass and power with or without an isolated extensor exercise program in patients undergoing lumbar discectomy.

PATIENTS AND METHODS

In this prospective study, we examined 75 patients who had undergone discectomy between March 2002 and August 2002 at the Wooridul Spine Hospital, Seoul, Korea. The inclusion criteria were: 1) unilateral radiating leg pain with or without back pain not responding to conservative treatment methods and having a good radiological correlation; 2) first-time lumbar spine operation; 3) single-level disc herniation; and 4) absence of associated systemic diseases such as cardiac ailments or orthopedic contraindications for subsequent exercise program. Patients were randomized into two groups, a control group and an exercise group.

Among the 80 patients enrolled initially, exercise group consisted of 40 patients (23 men and 18 women), whereas the control group included 40 patients (18 men and 22 women). Among the exercise group, five patients dropped out. Two of them experienced increased pain, whereas the other three cited personal reasons. These five thus were excluded from the analyses.

All patients underwent a computed tomographic (CT) scan of the lumbar spine before operation to quantify the cross-sectional area of the longissimus and multifidus muscles at the upper endplate of the L4 vertebra. The CT scan measurements were taken by an independent observer using a software PiView program (Infinitt Co., Ltd., Seoul, Korea; *Fig. 1*). The axial slice of the lumbar spine was enlarged and the cursor identified the area of the multifidus and longissimus muscle. The software then calculated the area identified. Visual analog score (VAS) measurements for pain as well as the Oswestry Disability Index (ODI) were noted for all participants.

On discharge, all patients were given advice on maintaining proper posture and avoiding strenuous activities. Handouts also were given instructing them about basic lumbar conditioning exercises to be performed at home after the second postoperative week. The initial postoperative protocol was common until the sixth postoperative week.

At the end of the sixth postoperative week, all patients underwent measurement of the isometric strength of the extensor muscles of the lumbar spine using the MedX (Ocala, FL) system. This marked the baseline measurement. The measurements were obtained at various angles of lumbar flexion from 0 to 72 degrees. The maximal voluntary effort applied was calculated and was quantified by the machine as the torque generated (*Fig. 2*).

After the sixth postoperative week, the control group continued with the home-based basic lumbar conditioning exercises. The exercise group started with the intensive schedule with a defined set of exercises for extensor muscle strengthening for the next 12 weeks. It was a supervised and graded program that also included aerobic and limb-strengthening exercises. The exercises included both dynamic and isometric exercises for the lumbar extensors. This exercise program used the MedX system, which by restricting the hip and pelvic motion using restraints, isolates the lumbar extensor muscles. Also, progressive resistance exercises can be given by increasing the weight.

At the end of the 12-week program (eighteenth postoperative week), all patients, including the control group, again underwent CT scanning of the lumbar spine for cross-sectional area measurements of the longissimus and the multifidus, in addition to the strength of the erector spinae being calculated by the MedX system. The VAS for pain and the ODI also were noted. The patients were then followed up to assess their return to work. At the end of 1 year, all patients were evaluated for pain by VAS.

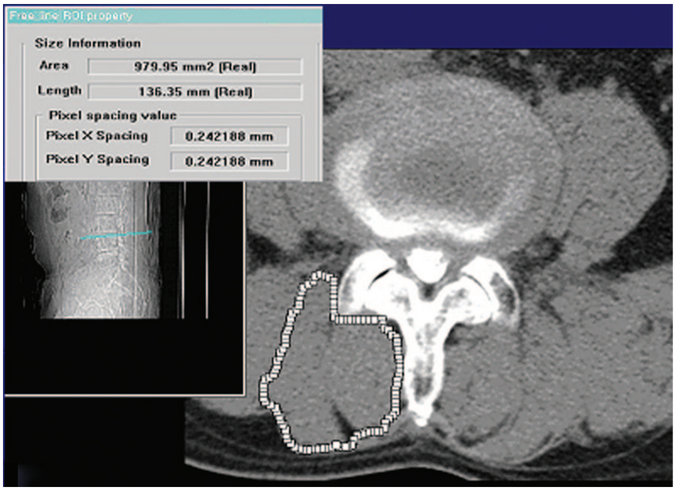

FIGURE 1. *Cross-sectional area measurement of the longissimus and multifidus muscles using a CT scan at the upper endplate of the L4–L5 body.*

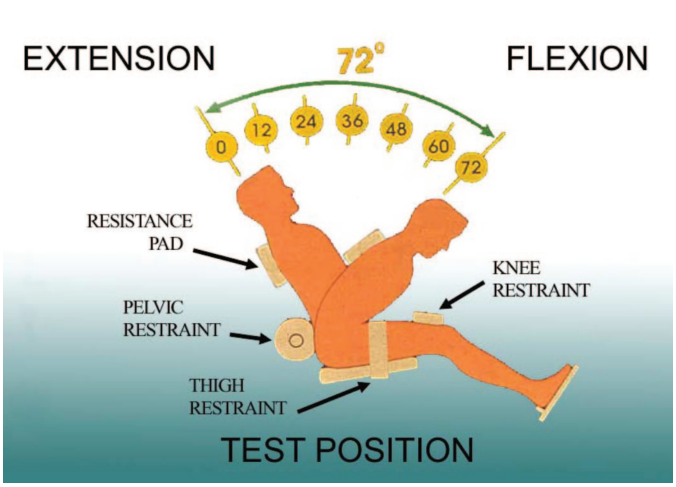

FIGURE 2. *Illustration showing the position for measurement of isometric strength of lumbar extensor muscles at various angles of lumbar flexion using the MedX lumbar extension system (Ocala, FL).*

TABLE 1. Characteristics of the exercise and control groups[a]

Group	n	Age (yr)	Height (cm)	Weight (kg)
Exercise	35 (M, 20; F, 15)	51.05 ± 9.58	164.95 ± 8.05	63.62 ± 8.20
Control	40 (M, 18; F, 22)	42.02 ± 17.06	165.34 ± 7.30	67.62 ± 12.34

[a]M, male; F, female. Data are presented as mean ± standard deviation.

Statistical Analysis

The means and standard deviations in both the exercise and control groups were calculated, and the difference for each group was compared. Also, the result including change (%) between, before and after the 12-week exercise program, was analyzed. Statistical analysis was performed using an independent and paired t test, and all P values less than 0.05 were determined to be statistically significant.

RESULTS

General Characteristics of the Exercise and Control Groups

Seventy-five patients were divided randomly into the exercise (20 men, 15 women) and control groups (18 men, 22 women). The mean age of all the patients was 46.09 years (exercise group, 51.05 ± 9.58 yr; control group, 42.02 ± 17.06 yr), the mean height of all patients was 165.44 cm (exercise group, 164.95 ± 8.95 cm; control group, 165.34 ± 7.30 cm), and the mean weight of all patients was 65.84 kg (exercise group, 63.62 ± 8.20 kg; control group, 67.62 ± 12.34 kg; *Table 1*).

Comparison of Lumbar Extensor Power Between Exercise and Control Groups

The lumbar extensor power in both groups improved at the end of eighteenth postoperative week. The improvement in the exercise group was statistically significant compared with the control group (0–48 degree of angle, $P < 0.01$; 60 degree, $P < 0.05$). However, there was no statistically significant difference between two groups when tested at 72 degrees of lumbar flexion ($P > 0.05$).

The mean lumbar extensor power at seven different angles in the exercise and control groups improved by 51.67% and 17.55%, respectively, compared with the preoperative data. After a 12-week lumbar extension exercise program, the mean extensor power in the exercise group (162.57 ± 43.20) was higher by 34.12% than that of control group (134.14 ± 47.79), and this result was statistically significant ($P < 0.01$; $P < 0.05$). Therefore, these results support idea that the lumbar extension exercise program leads to obvious improvement in the lumbar extensor power (*Table 2*).

Cross-sectional Area of Muscle Mass of Erector Spinalis

According to the change of cross-sectional area of longissimus and multifidus muscle mass in each group after a 12-week lumbar extension exercise program, the cross-sectional area in the exercise group (mean, 4197.89 ± 980.39 mm^2) was shown to be higher by 20.55% compared with that of the control group (mean, 3555.20 ± 721.89 mm^2; $P < 0.05$). This

TABLE 2. Mean lumbar extensor power at seven different angles in the exercise and control groups

Group	Angle	Weeks 0[a]	12[a]	24[a]	36[a]	48[a]	60[b]	72	Mean	Improvement (%)
Exercise	Before test	65.96 ± 31.82	83.48 ± 21.03	95.68 ± 22.32	111.20 ± 23.08	118.00 ± 28.47	130.65 ± 30.67	145.30 ± 38.45	107.18 ± 27.98	51.67
	After test	108.31 ± 29.32	130.40 ± 31.38	149.22 ± 40.92	166.25 ± 39.89	186.11 ± 46.59	195.94 ± 60.57	201.74 ± 53.73	162.57 ± 43.20	
Control	Before test	74.85 ± 34.68	94.90 ± 36.42	105.87 ± 37.15	115.70 ± 38.17	124.65 ± 37.23	130.92 ± 37.53	151.89 ± 39.64	114.11 ± 37.28	17.55
	After test	78.05 ± 40.83	106.82 ± 39.27	125.00 ± 41.92	139.05 ± 47.40	148.36 ± 48.97	161.54 ± 63.16	180.16 ± 53.00	134.14 ± 47.79	

[a]$P < 0.01$. [b]$P < 0.05$.

fact establishes that extension exercise can result in hypertrophy of erector spinalis (*Table 3*).

VAS

VAS was largely decreased in both the exercise and control group after 12 weeks of extension exercise. Because the decreased VAS in the exercise group was significantly larger than that of the control group ($P < 0.05$), the extension exercise program is one of the factors that influences postoperative pain relief. When assessed at the end of 1 year, the pain levels in both the control and exercise groups were comparable, with no statistically significant difference (*Fig. 3*).

ODI Score

Although there was no statistically significant difference in ODI scores between the exercise and control group (24.6 and 30.6, respectively; $P > 0.05$), in both the groups, the postoperative ODI scores were improved compared with preoperative ODI scores (*Fig. 4*).

Return to Work

In both groups, more than 92% of patients could return to work within 6 months after the surgery. Whereas 87% of patients in the exercise group returned to work within 4 months, 24% in control group did, and one patient could not return to work up to 6 months. Therefore, this difference in return to work between the two groups shows that the exercise program and strengthening of muscle power resulted in faster return to work and normal life activities (*Fig. 5*).

DISCUSSION

After successful operation for radicular pain with discectomy, the incidence of persistent low back pain with radicular pain is variable and is reported to be between 40 and 60% (9, 11). One of the reasons cited for poor results after discectomy is the lack of adequate muscle strength and endurance in the back muscles.

The role of the paraspinal muscles in the maintenance of the equilibrium and optimum function of the spine as a whole is well studied (13, 37). Paraspinal muscle atrophy has been documented radiographically in patients with chronic low back pain as compared to healthy individuals (6, 8). There is definite histological evidence of microscopic changes demonstrating atrophy in multifidus muscle in patients with disc herniation (24, 30). In patients undergoing posterior lumbar surgical procedures, there is a further chance of denervation atrophy resulting from damage to the dorsal rami (21, 43, 46). Kahanovitz et al. (20) reported an approximately 30% decrease in trunk muscle strength after discectomy operation. There is a strong relationship between multifidus muscle dysfunction and poor functional outcome with recurrence of low back pain after disc surgery (41, 43). The weakness of the paraspinal muscles can thus predispose patients to further instability and dysfunction, leading to a high recurrence rate for low back pain. Also, ineffective muscular stabilization of the spine results in an increased risk of injury.

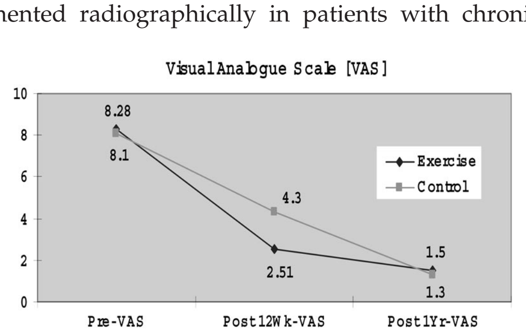

FIGURE 3. *Graph demonstrating the change in the VAS for pain before and after the exercise program in the exercise and control groups.*

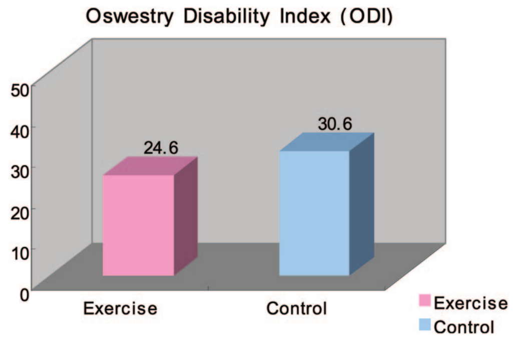

FIGURE 4. *Bar graph demonstrating the change in the ODI score in the control and exercise groups at the eighteenth postoperative week.*

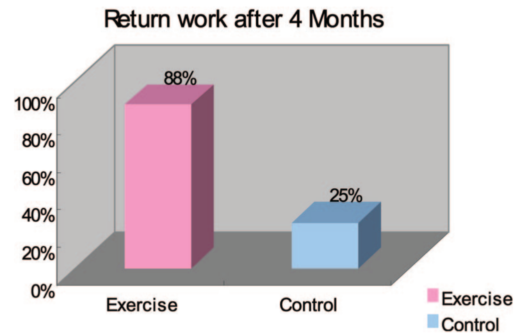

FIGURE 5. *Bar graph demonstrating number of patients in the control and exercise groups who returned to work 4 months after surgery.*

The most important aim of surgical intervention for sciatica is early functional return of the patient. The return to work is dependent on the pain-free status guaranteed by the operation, but also can be improved by exercises to restore back muscle function, which has been impaired by prolonged inactivity as well as reflex inhibition resulting from pain or from the surgical procedure itself.

In a prospective controlled study, Millisdotter et al. (33) concluded that proximal muscular dysfunction frequently is present in patients with disc herniation, and whereas sciatica usually resolves quickly after discectomy, the disability im-

TABLE 3. Change of cross-sectional area of muscle mass

Group	Before 12 wk (mm^2)	After 12 wk (mm^2)	Improvement (%)	Difference (%)[a]
Exercise	3428.22 ± 665.76	4197.89 ± 980.39	29.23	22.03
Control	3316.41 ± 723.01	3555.20 ± 721.81	7.20	

[a] $P < 0.05$.

proves gradually up to 4 months and the muscular performance improves throughout 1 year after surgery.

Leinonen et al. (25) studied the lumbar paraspinal muscle function, perception of lumbar position, and postural control in disc herniations related to back pain before and after discectomy. The results demonstrated that the patients with sciatica had impaired proprioception and postural control. After discectomy, the lumbar proprioception did change positively, but the postural control did not change. This study demonstrates the necessity of exercise therapy for functional recovery of patients.

Hakkinen et al. (17) evaluated trunk muscle strength, pain, flexibility, and disability in patients who had been operated for lumbar disc herniation 2 months after surgery. Although the leg pain and back pain decreased by approximately 80%, 30% of the patients perceived moderate to severe disability measured by ODI score. It was also noted that decreased muscle strength and mobility, especially with older patients and with considerable postoperative pain, caused significant functional disability. The authors recommend early identification of those patients with restrictions so that rehabilitation exercises can begin as soon as possible. Another important observation by them was that the ratio of trunk extension to flexion strength had changed in favor of flexion muscles. Thus to reverse this, more extensor muscle exercise is needed.

Similar decrease in the trunk muscle strengths after discectomy as compared with healthy individuals was shown by Hakkinen et al. (16). They showed that even after operative treatment of disc herniation, at 2 months after surgery, the extensor strength was less than that of the healthy control group. The recovery of maximal endurance is incomplete in the patients, and thus there is a need for active training to improve strength of the trunk muscles after discectomy.

Exercises have shown to be effective to improve pain and disability in patients with non specific chronic low back pain (12, 26, 27, 40, 42). Activity restriction after microdiscectomy initially was advised to prevent disc reinjury and complications arising thereafter, but it has been shown that restriction of activity after limited discectomy is not necessary in most patients (4, 5). Indeed, there are reports of improved outcomes regarding pain, disability, and functional recovery with exercise regimens after discectomy (1, 3, 7, 9, 10, 17, 19, 28, 29, 36, 39, 44, 45). Danielsen et al. (7) showed that because the clinical end points in patients with or without aggressive exercise therapy remain the same, there is no danger of aggravation of symptoms with aggressive exercise begun 4 weeks after discectomy.

There is considerable debate regarding whether to advise flexion or extension exercises or both (45), but extension exercises have been shown to improve the flexibility of the spine and to cause unloading of the disc and are also generally well tolerated by the operated patient (28, 32). In a prospective study evaluating the association of trunk muscle weakness with low back pain, Lee et al. (23) concluded that an imbalance in trunk muscle strength, that is, lower extensor muscle strength than flexor muscle strength, may be one risk factor for low back pain. We also believe that because there is also some disruption of the extensor muscles as a result of operative intervention, there is a need to concentrate on extensor muscle strengthening in the initial intensive phase of rehabilitation.

The recovery of multifidus muscle is not spontaneous after resolution of painful symptoms, and this inhibition can be reversed only by specific training exercises. This then can prevent the subsequent incidence of low back pain and thus also prevent recurrences (18). Although there is strong evidence that intensive exercise programs are more effective on functional status and faster return to work after discectomy (1, 7, 9, 10, 11, 16, 22, 29, 36, 39, 45), the objective data on muscle strength improvement and clinical correlation are scarce. Our study provides quantitative data in the form of muscle strength as measured using a lumbar extension machine and a cross-sectional area of longissimus and multifidus muscles as measured on CT scan after exercise therapy after discectomy and its correlation with the clinical outcome as compared with those patients not undergoing intensive extensor exercise therapy. The force of contraction of a muscle as well as the strength depends on its cross sectional area. Thus, measurement of the cross-sectional area gives us the indirect quantitative assessment of muscle strength and power.

Danneels et al. (8) and Mayer et al. (31) confirmed the reliability of CT measurements of the paraspinal muscle cross-sectional area in patients with chronic low back pain and postoperative patients, respectively. We used cross-sectional area measurements of the longissimus and the multifidus at the level of the upper endplate of L4 in our study. Use of the MedX system makes it possible to calculate the strength of the muscles as well as to provide effective resistance exercise on a graded level to the patient at various angles of extension or flexion. Pelvic stabilization is needed in isolation of the lumbar extensors. With pelvic stabilization, the lumbar extensors show an abnormally large potential for strength increase (14). Use of the MedX system also enables use of pelvic stabilization, and thus the extensors of the spine are trained more effectively, independent of the hip extensors (15). Isometric extension strength testing at different angles of lumbar flexion is helpful in assessing the strength over the entire range of motion (38). Training frequency as low as once weekly provides an effective training stimulus for the development of lumbar extension strength. Isometric exercises can develop strength in extensors (14). We required the patients to report to the rehabilitation department twice weekly to undergo the exercise regimen.

In the present study, the CT scan measurements for cross-sectional area before surgery did not show any significant difference between the control and exercise groups. We did not compare the same with any normative data in healthy patients, and so cannot infer its significance. The extensor power measurements using the lumbar extension machine at the sixth postoperative week also did not show any significant difference in the control and exercise groups. Thus, although we used a simple randomization procedure for grouping, there was no statistical difference between the control and exercise groups from the beginning. There was a significant improvement in the muscle strength for lumbar extensor muscles after an extensor strengthening program, and this was paralleled with a simultaneous increase in the cross-sectional area of longissimus and multifidus muscle. Untrained patients usually were much weaker at full extension than they were in the flexed position. Loss of leverage as you move from the flexed position may appear to be responsible for the lower level of strength in the extended position. But trained patients, after their initial level of strength has been greatly increased by specific exercise, usually produce the same level of true muscular strength, in every position throughout a full range of movement. Muscular strength was statistically significant at all the angles of lumbar flexion except at 72 degrees. An intensive exercise schedule thus enables objective improvement in the strength of the back muscles, which is uniform throughout the range of motion.

Further, VASs were lower in the exercise group at the end of eighteenth postoperative week than in the control group. The return to work was also earlier, and 87% of the patients from the exercise group returned to work even while still participating in the exercise program within 4 months after surgery. We also found that the difference in the pain status was comparable at the end of 1 year, with no statistically significant change between the exercise and control groups. These observations are comparable with previous studies in this regard mentioned in the Cochrane Review (35). Thus, an active exercise program for the lumbar extensors aids faster relief of pain and earlier restoration of functional abilities, which is of prime importance.

We did not evaluate which of the patients continued with the home-based exercise schedule after the end of the intensive program when assessed at the end of 1 year. It is necessary to evaluate the long-term effects of an intensive exercise program followed by a home-based schedule in operated patients and the future recurrences of pain or the need to undergo surgery. We are not sure how long the benefits of the intensive exercise schedule last after it is discontinued. But this helps in motivating the patients and achieving a baseline improvement in their back power on which they can build their future course. We believe that such exercise programs also may have a long-term effect in preventing the chances of recurrent low back pain subsequently.

These findings need further investigation and long-term evaluation. There were no patients in either group who required repeat surgery in the first year of follow-up. Thus exercise does not seem to increase the chance of reinjury or resurgery, and neither does it seem to avoid it. The advantages of intensive postoperative rehabilitation programs after first-time discectomy not only are limited to the individual, but also have considerable benefits with respect to socioeconomic benefits resulting from increased productivity (2). A rehabilitation-oriented approach enables more patients to return to work after discectomy (10). Active participation in the rehabilitation process enables patients to have a positive effect on the way they cope with pain in their daily lives (22).

CONCLUSION

The introduction of lumbar extension exercises after surgery in patients undergoing discectomy helps achieve an early return to work and also improves spinal function and pain. The exercise regimen increases the cross-sectional area of longissimus and multifidus muscle with parallel increase in strength and endurance as quantified objectively.

REFERENCES

1. Alaranta H, Hurme M, Einola S, Kallio V, Knuts LR, Torma T: Rehabilitation after surgery for lumbar disc herniation: Results of a randomized clinical trial. **Int J Rehabil Res** 9:247–257, 1986.
2. Ankjaer-Jensen A, Manniche C, Nielsen H: Postoperative rehabilitation of patients operated for lumbar disk prolapse. An analysis of the socioeconomic consequences. **Ugeskr Laeger** 156:647–652, 1931.
3. Brennan GP, Shultz BB, Hood RS, Zahniser JC, Johnson SC, Gerber AH: The effects of aerobic exercise after lumbar microdiscectomy. **Spine** 19:735–739, 1994.
4. Carragee EJ, Han MY, Yang B, Kim DH, Kraemer H, Billys J: Activity restrictions after posterior lumbar discectomy. A prospective study of outcomes in 152 cases with no postoperative restrictions. **Spine** 24:2346–2351, 1999.
5. Carragee EJ, Helms E, O'Sullivan GS: Are postoperative activity restrictions necessary after posterior lumbar discectomy? A prospective study of outcomes in 50 consecutive cases. **Spine** 21:1893–1897, 1996.
6. Cooper RG, St Clair Forbes W, Jayson MI: Radiographic demonstration of paraspinal muscle wasting in patients with chronic low back pain. **Br J Rheumatol** 31:389–394, 1992.
7. Danielsen JM, Johnsen R, Kibsgaard SK, Hellevik E: Early aggressive exercise for postoperative rehabilitation after discectomy. **Spine** 25:1015–1020, 2000.
8. Danneels LA, Vanderstraeten GG, Cambier DC, Witvrouw EE, De Cuyper HJ: CT imaging of trunk muscles in chronic low back pain patients and healthy control subjects. **Eur Spine J** 9:266–272, 2000.
9. Dolan P, Greenfield K, Nelson RJ, Nelson IW: Can exercise therapy improve the outcome of microdiscectomy? **Spine** 25:1523–1532, 2000.
10. Donceel P, Du Bois M, Lahaye D: Return to work after surgery for lumbar disc herniation. A rehabilitation-oriented approach in insurance medicine. **Spine** 24:872–876, 1999.
11. Dvorak J, Gauchat MH, Valach L: The outcome of surgery for lumbar disc herniation. I. A 4-17 years' follow-up with emphasis on somatic aspects. **Spine** 13:1418–1422, 1988.

12. Frost H, Klaber Moffett JA, Moser JS, Fairbank JC: Randomised controlled trial for evaluation of fitness programme for patients with chronic low back pain. **BMJ** 310:151–154, 1995.
13. Goel VK, Kong W, Han JS, Weinstein JN, Gilbertson LG: A combined finite element and optimization investigation of lumbar spine mechanics with and without muscles. **Spine** 18:1531–1541, 1993.
14. Graves JE, Pollock ML, Foster D, Leggett SH, Carpenter DM, Vuoso R, Jones A: Effect of training frequency and specificity on isometric lumbar extension strength. **Spine** 15:504–509, 1990.
15. Graves JE, Webb DC, Pollock ML, Matkozich J, Leggett SH, Carpenter DM, Foster DN, Cirulli J: Pelvic stabilization during resistance training: Its effect on the development of lumbar extension strength. **Arch Phys Med Rehabil** 75:210–215, 1994.
16. Hakkinen A, Kuukkanen T, Tarvainen U, Ylinen J: Trunk muscle strength in flexion, extension, and axial rotation in patients managed with lumbar disc herniation surgery and in healthy control subjects. **Spine** 28:1068–1073, 2003.
17. Hakkinen A, Ylinen J, Kautiainen H, Airaksinen O, Herno A, Tarvainen U, Kiviranta I: Pain, trunk muscle strength, spine mobility and disability following lumbar disc surgery. **J Rehabil Med** 35:236–240, 2003.
18. Hides JA, Richardson CA, Jull GA: Multifidus muscle recovery is not automatic after resolution of acute, first-episode low back pain. **Spine** 21:2763–2769, 1996.
19. Johannsen F, Remvig L, Kryger P, Beck P, Lybeck K, Larsen LH, Warming S, Dreyer V: Supervised endurance exercise training compared to home training after first lumbar diskectomy: A clinical trial. **Clin Exp Rheumatol** 12:609–614, 1994.
20. Kahanovitz N, Viola K, Gallagher M: Long-term strength assessment of postoperative diskectomy patients. **Spine** 14:402–403, 1989.
21. Kawaguchi Y, Matsui H, Tsuji H: Back muscle injury after posterior lumbar spine surgery. A histologic and enzymatic analysis. **Spine** 21:941–944, 1915.
22. Kjellby-Wendt G, Styf J, Carlsson SG: Early active rehabilitation after surgery for lumbar disc herniation: A prospective, randomized study of psychometric assessment in 50 patients. **Acta Orthop Scand** 72:518–524, 2001.
23. Lee JH, Hoshino Y, Nakamura K, Kariya Y, Saita K, Ito K: Trunk muscle weakness as a risk factor for low back pain. A 5-year prospective study. **Spine** 24:54–57, 1999.
24. Lehto M, Hurme M, Alaranta H, Einola S, Falck B, Jarvinen M, Kalimo H, Mattila M, Paljarvi L: Connective tissue changes of the multifidus muscle in patients with lumbar disc herniation. An immunohistologic study of collagen types I and III and fibronectin. **Spine** 14:302–309, 1989.
25. Leinonen V, Kankaanpaa M, Luukkonen M, Kansanen M, Hanninen O, Airaksinen O, Taimela S: Lumbar paraspinal muscle function, perception of lumbar position, and postural control in disc herniation-related back pain. **Spine** 28:842–848, 2003.
26. Liddle SD, Baxter GD, Gracey JH: Exercise and chronic low back pain: What works? **Pain** 107:176–190, 2004.
27. Maher CG: Effective physical treatment for chronic low back pain. **Orthop Clin N Am** 35:57–64, 2004.
28. Manniche C, Asmussen K, Lauritsen B, Vinterberg H, Karbo H, Abildstrup S, Fischer-Nielsen K, Krebs R, Ibsen K: Intensive dynamic back exercises with or without hyperextension in chronic back pain after surgery for lumbar disc protrusion. A clinical trial. **Spine** 18:560–567, 1993.
29. Manniche C, Skall HF, Braendholt L, Christensen BH, Christophersen L, Ellegaard B, Heilbuth A, Ingerslev M, Jorgensen OE, Larsen E: Clinical trial of postoperative dynamic back exercises after first lumbar discectomy. **Spine** 18:92–97, 1993.
30. Mattila M, Hurme M, Alaranta H, Paljarvi L, Kalimo H, Falck B, Lehto M, Einola S, Jarvinen M: The multifidus muscle in patients with lumbar disc herniation. A histochemical and morphometric analysis of intraoperative biopsies. **Spine** 11:732–738, 1986.
31. Mayer TG, Vanharanta H, Gatchel RJ, Mooney V, Barnes D, Judge L, Smith S, Terry A: Comparison of CT scan muscle measurements and isokinetic trunk strength in postoperative patients. **Spine** 14:33–36, 1989.
32. McKenzie R: Acute low back ache and exercises. **N Z Med J** 107:318, 1994.
33. Millisdotter M, Stromqvist B, Jonsson B: Proximal neuromuscular impairment in lumbar disc herniation: a prospective controlled study. **Spine** 28:1281–1289, 2003.
34. Nygaard OP, Romner B, Trumpy JH: Duration of symptoms as a predictor of outcome after lumbar disc surgery. **Acta Neurochir (Wien)** 128:53–56, 1994.
35. Ostelo RW, de Vet HC, Waddell G, Kerckhoffs MR, Leffers P, van Tulder MW: Rehabilitation after lumbar disc surgery. (Cochrane Review), in The Cochrane Database of Systematic Reviews. Oxford Software, 2002, 2:CD003007.
36. Ostelo RW, de Vet HC, Waddell G, Kerckhoffs MR, Leffers P, van Tulder M: Rehabilitation following first-time lumbar disc surgery: A systematic review within the framework of the Cochrane collaboration. **Spine** 28:209–218, 2003.
37. Panjabi MM: The stabilizing system of the spine. Part I. Function, dysfunction, adaptation, and enhancement. **J Spinal Disord** 5:383–389; discussion 397, 1992.
38. Pollock ML, Leggett SH, Graves JE, Jones A, Fulton M, Cirulli J: Effect of resistance training on lumbar extension strength. **Am J Sports Med** 17:624–629, 1989.
39. Postacchini F, Montanaro A: Early mobilisation and functional re-education in the post operative treatment of prolapsed lumbar disc. **Ital J Orthop Traumatol** 4:231–236, 1978.
40. Rainville J, Hartigan C, Martinez E, Limke J, Jouve C, Finno M: Exercise as a treatment for chronic low back pain. **Spine J** 4:106–115, 2004.
41. Rantanen J, Hurme M, Falck B, Alaranta H, Nykvist F, Lehto M, Einola S, Kalimo H: The lumbar multifidus muscle five years after surgery for a lumbar intervertebral disc herniation. **Spine** 18:568–574, 1993.
42. Risch SV, Norvell NK, Pollock ML, Risch ED, Langer H, Fulton M, Graves JE, Leggett SH: Lumbar strengthening in chronic low back pain patients. Physiologic and psychological benefits. **Spine** 18:232–238, 1993.
43. Sihvonen T, Herno A, Paljarvi L, Airaksinen O, Partanen J, Tapaninaho A: Local denervation atrophy of paraspinal muscles in postoperative failed back syndrome. **Spine** 18:575–581, 1993.
44. Skall FH, Manniche C, Nielsen CJ: Intensive back exercises 5 weeks after surgery of lumbar disk prolapse. A prospective, randomized multicenter trial with a historical control group. **Ugeskr Laeger** 156:643–646, 1931.
45. Yilmaz F, Yilmaz A, Merdol F, Parlar D, Sahin F, Kuran B: Efficacy of dynamic lumbar stabilization exercise in lumbar microdiscectomy. **J Rehabil Med** 35:163–167, 2003.
46. Zoidl G, Grifka J, Boluki D, Willburger RE, Zoidl C, Kramer J, Dermietzel R, Faustmann PM: Molecular evidence for local denervation of paraspinal muscles in failed-back surgery/postdiscotomy syndrome. **Clin Neuropathol** 22:71–77, 2003.

Acknowledgments

The authors thank Chigon Oh, Sung-Hee Myung, and Ji-Hee Hwang for their help in the preparation of this manuscript. This work was presented at the Congress of Neurological Surgeons, 2003, in Denver, Colorado.

COMMENTS

Dr. Choi et al. have provided data that supports an early reconditioning program after lumbar spine surgery. This observation may be intuitive to some. In spite of this, few surgeons utilize such a strategy clinically. Hopefully, work such as this will convince the surgical community of the importance of adjunctive management strategies. For this alone, the authors are to be congratulated. However, I feel compelled to further emphasize the importance of exercise programs. With such programs, patient compliance is mandatory. In this vein, the utilization of specialized equipment, as was employed in this study, is not necessary for the achievement of good clinical results from exercise and reconditioning programs. In fact, it may detract from patient involvement (compliance) in the process. Of greater importance, the cost incurred by utilizing unnecessary technology must be taken into account.

Edward C. Benzel
Cleveland, Ohio

The most important aspect of the paper is that there is no effective control in the study. The only comparison being made is an early return to function as opposed to a totally random return to function. The type of exercising done is irrelevant to the results in these patients. The conclusions and the results of the study should not reflect that extension exercises are an effective postoperative treatment method.

As a general rule, for most spinal surgeons, a microscopic lumbar discectomy should be an outpatient or over night stay procedure, with ambulation beginning immediately after the patient wakes up from anesthesia. Progressive ambulation to as much as five miles two times a day a few weeks after the surgery and beginning a core stabilization training exercise program as soon as 10 days after the surgery are recommended. Core stabilization certainly is preferred over flexion or extension program because the spine is locked in a neutral, pain free position, and the exercises are conducted while maintaining this position. There can be no safer method of doing back strengthening after microscopic lumbar discectomy than maintaining a neutral, pain-free position. The role of the therapist or trainer is to teach the patient the neutral position, teach them the exercises, and conduct their exercises with the patient while observing whether they are able to maintain their neutral position. When the patient loses control of their spine in an exercise, then the exercise is stopped and a different exercise is begun.

A major key to rehabilitation of the spine is coordinated trunk strength. This protects the spine through muscle activity that decreases abnormal motion in the spine. Incidentally, high-performance athletic activity and work activity involves the same coordinated trunk muscles to protect the spine. Instituting balance and coordination exercises from the beginning of the rehabilitation program is critical to a rapid, successful return to full activity.

Resistive flexion and extension in a flexion or extension machine is a nonphysiologic motion and it is a motion that is rarely used in athletic activity or in work activity. Loaded resistive motion through an injured or recently operated joint is activity that can injure the joint. Certainly, core stabilization loads the joint, but neutral loading is safer than loading through a ROM. Core stabilization training allows the muscles to respond to changes in proprioception and overall body balance. It enhances a coordinated muscle response to this change in body balance from a safe, neutral spine position. Rapid return to function after a microscopic lumbar discectomy is of vital importance. A low recurrent herniation rate and ultimate patient satisfaction from low morbidity is the goal. For a significant portion of the patients who are begun on a lumbar motion program, they are more likely to sustain lumbar injury in the postoperative period and more likely to become symptomatic than would be patients with neutral spine training.

Robert Watkins
Spinal Orthopedic Surgeon
Los Angeles, California

Dr. Choi et al. have contributed an important observation on the beneficial effect of early postoperative exercise on outcome and return to work following low back surgery. This supports the published beneficial effects of stretching and strengthening exercises for low back pain and radiculopathy. Furthermore, it is particularly applicable to patients undergoing minimally invasive spinal procedures. What it suggests is that prolonged restricted activities, and the consequent deconditioning that result, are ultimately delaying recovery. Early mobilization and supervised exercise programs should be the postoperative routine for all surgeons performing low back surgery.

Richard G. Fessler
Chicago, Illinois

In light of findings that show weakness of the trunk muscles and segmental instability may occur after lumbar diskectomy surgery (11, 15, 28), the article by Dr. Choi et al. examining postoperative spinal rehabilitation is timely and relevant to current discussion. The conclusions presented by the authors regarding improved patient functional outcomes in the experimental arm of the study merit further investigation. The authors state in their conclusion that the tested exercise regimen resulted in improved spinal function and pain. As noted in the article, no statistical differences were found between the scores of the experimental and control groups on the Oswestry Disability Index (the only functional outcome measure reported in the study). Further, no difference existed between groups in the return to work rates 6 months postoperatively. This calls into question the clinical significance of the large reported difference in return-to-work rates noted between groups at the 4 months measure. Carragee et al. (2) found that patients instructed to return to full occupational activities as soon as they believed they were able returned to work in a mean time of 1.7 weeks after lumbar diskectomy surgery. Failure by Dr. Choi et al. to report the criteria that led to subjects returning to work in their study further clouds the clinical relevance of the reported difference at the 4-months measure.

The usefulness of maximal isometric contraction spinal extension torque measurements and training in postoperative spinal rehabilitation care also remains unclear. Previous research indicates that measurement of maximal voluntary isometric contraction values of trunk extension is poor at discriminating patients with low back pain from pain-free individuals and has limited utility (14). It is noteworthy that, although the authors assert that increased cross sectional area of the paraspinal muscles provides a quantitative measure of muscle strength and power, their findings at baseline measurement contradict this statement. Examination of Tables 2 and 3 reveals that the control group generated greater spinal extension torque than the experimental group at baseline for every one of the seven measured trunk angles despite exhibiting smaller mean cross sectional areas of the multifidus and longissimus muscles. While prior research supports the authors' contention that paraspinal muscle cross-sectional area is one determinant of isometric trunk muscle strength other factors may be more essential in predicting and improving patient outcomes after lumbar discectomy surgery (24). Recent research indicates that impaired muscle performance of the lumbar paraspinals in patients with low back pain may result from altered muscle recruitment patterns and poor endurance rather than power generated by the spinal extensor muscles (7, 9, 10, 19, 25, 26). Training of the spinal extensor muscles in isolation may not impart any advantage in spinal function during activities of daily living, as functional demands typically require the coordinated action of multiple muscle groups of the trunk (16, 21, 27). Granata and Orishimo found that co-contraction of the spinal flexors and extensors occurs during simulated lifting tasks (3). They concluded that the concurrent activity of the spinal extensors and flexors is necessary in order to maintain equilibrium as trunk stiffness increases in response to the demands of the lifting activity. McGill (16) and Panjabi et al. (22, 23) have described the means by which the coordinated activity of multiple muscle groups can control trunk posture during functional activities, minimizing the loads placed on vulnerable spinal structures.

Impaired control of the neutral zone of motion of the lumbar spine, described by Panjabi (22, 23), is associated with excessive tissue stress that may lead to increased intersegmental injury and intervertebral disc degeneration (1, 12, 17, 21, 23, 27). Research indicates that activation of the multifidi and the transversus abdominis muscles increases stiffness coefficients of individual vertebral segments within the neutral zone of motion, potentially imparting stability to the spine (8, 9, 12, 30). Dr. Choi and his colleagues, citing research by Hides et al. (5), report that changes in the multifidus muscle cross sectional area which occur after injury are not spontaneously reversed when patients recover from an episode of low back pain. However, Dr. Choi et al. neglect to note results of research by Hides et al. (4, 5) and O'Sullivan (20) that utilized physical therapists to train patients to maintain spinal postures within the neutral zone of motion. This work indicated that an exercise program of spinal segmental stabilization, via submaximal co-contraction of the multifidi and deep abdominal muscles, reverses multifidus atrophy and reduces injury recurrence rates in patients with low back pain. Yilmaz et al. (31) found that treatment emphasizing segmental stabilization in the neutral zone was more effective after lumbar microdiskectomy surgery than a treatment program that included flexion-extension exercises along with global trunk strengthening or a program of medical management without exercise.

It is a widely held belief that the effects of exercise are closely linked to the context in which exercise training occurs. The maximal functional carryover of exercise is attained when training speeds, muscle contraction parameters, and joint angles most closely resemble demands placed upon muscles during activities of daily living (6, 13, 18, 29). Recent clinical research in this area has emphasized retraining the multifidi muscles to fire synchronously with the transversus abdominis muscle in a variety of postures under varying demands. In an effort to maximize functional gains, patients' programs are typically progressed by training, then they apply these same techniques while performing simulated activities of daily living. The article by Dr. Choi et al. has contributed to the understanding of the physiological changes that occur with a postsurgical exercise regimen of maximal isometric contraction of the multifidus and longissimus muscles. Regrettably, the authors have presented conclusions regarding functional gains that are not well supported by the evidence presented in their paper. We believe it important to convey the larger motor control issues that impact on the rehabilitation of patients after surgery of the lumbar spine.

Evan K. Johnson
Paul C. McCormick
New York, New York

1. Atlas OK, Dodds SD, Panjabi MM: Single and incremental trauma models: a biomechanical assessment of spinal instability. **Eur Spine J** 12:205–210, 2003.
2. Carragee EJ, Helms E, O'Sullivan GS: Are postoperative activity restrictions necessary after posterior lumbar discectomy? A prospective study of outcomes in 50 consecutive cases. **Spine** 21:1893–1897, 1996.
3. Granata KP, Orishimo KF: Response of trunk muscle coactivation to changes in spinal stability. **J Biomech** 34:1117–1123, 2001.
4. Hides JA, Jull GA, Richardson CA: Long-term effects of specific stabilizing exercises for first-episode low back pain. **Spine** 26:E243-248, 2001.
5. Hides JA, Richardson CA, Jull GA: Multifidus muscle recovery is not automatic after resolution of acute, first-episode low back pain. **Spine** 21:2763–2769, 1996.
6. Higbie EJ, Cureton KJ, Warren GL 3rd, Prior BM: Effects of concentric and eccentric training on muscle strength, cross-sectional area, and neural activation. **J Appl Physiol** 81:2173–2181, 1996.
7. Hodges PW: Changes in motor planning of feedforward postural responses of the trunk muscles in low back pain. **Exp Brain Res** 141:261–266, 2001.
8. Hodges P, Kaigle Holm A, Holm S, Ekstrom L, Cresswell A, Hansson T, Thorstensson A: Intervertebral stiffness of the spine is increased by evoked contraction of transversus abdominis and the diaphragm: in vivo porcine studies. **Spine** 28:2594–2601, 2003.
9. Hodges PW, Richardson CA: Inefficient muscular stabilization of the lumbar spine associated with low back pain. A motor control evaluation of transversus abdominis. **Spine** 21:2640–2650, 1996.
10. Hodges PW, Richardson CA: Altered trunk muscle recruitment in people with low back pain with upper limb movement at different speeds. **Arch Phys Med Rehabil** 80:1005–1012, 1999.
11. Kahanovitz N, Viola K, Gallagher M: Long-term strength assessment of postoperative diskectomy patients. **Spine** 14:402–403, 1989.
12. Kaigle AM, Holm SH, Hansson TH: Experimental instability in the lumbar spine. **Spine** 20:421–430, 1995.
13. Kanehisa H, Miyashita M: Specificity of velocity in strength training. **Eur J Appl Physiol Occup Physiol** 52:104–106, 1983.
14. Klein AB, Snyder-Mackler L, Roy SH, DeLuca CJ: Comparison of spinal mobility and isometric trunk extensor forces with electromyographic spectral analysis in identifying low back pain. **Phys Ther** 71:445–454, 1991.
15. Kotilainen E, Valtonen S: Long-term outcome of patients who underwent percutaneous nucleotomy for lumbar disc herniation: results after a mean follow-up of 5 years. **Acta Neurochir (Wien)** 140:108–113, 1998.
16. McGill SM: Low back stability: from formal description to issues for performance and rehabilitation. **Exerc Sport Sci Rev** 29:26–31, 2001.
17. Mimura M, Panjabi MM, Oxland TR, Crisco JJ, Yamamoto I, Vasavada A: Disc degeneration affects the multidirectional flexibility of the lumbar spine. **Spine** 19:1371–1380, 1994.
18. Morrissey MC, Harman EA, Johnson MJ: Resistance training modes: specificity and effectiveness. **Med Sci Sports Exerc** 27:648–660, 1995.
19. Oddsson LI, Giphart JE, Buijs RJ, Roy SH, Taylor HP, De Luca CJ: Development of new protocols and analysis procedures for the assessment of LBP by surface EMG techniques. **J Rehabil Res Dev** 34:415–426, 1997.
20. O'Sullivan PB, Phyty GD, Twomey LT, Allison GT: Evaluation of specific stabilizing exercise in the treatment of chronic low back pain with radiologic diagnosis of spondylolysis or spondylolisthesis. **Spine** 22:2959–2967, 1997.
21. Panjabi MM: Clinical spinal instability and low back pain. **J Electromyogr Kinesiol** 13:371–379, 2003.
22. Panjabi MM: The stabilizing system of the spine. Part II. Neutral zone and instability hypothesis. **J Spinal Disord** 5:390–396; discussion 397, 1992.
23. Panjabi M, Abumi K, Duranceau J, Oxland T: Spinal stability and intersegmental muscle forces. A biomechanical model. **Spine** 14:194–200, 1989.
24. Raty HP, Kujala U, Videman T, Koskinen SK, Karppi SL, Sarna S: Associations of isometric and isoinertial trunk muscle strength measurements and lumbar paraspinal muscle cross-sectional areas. **Journal of Spinal Disorders** 12:266–270, 1999.
25. Roy SH, De Luca CJ, Casavant DA: Lumbar muscle fatigue and chronic lower back pain. **Spine** 14:992–1001, 1989.
26. Roy SH, De Luca CJ, Snyder-Mackler L, Emley MS, Crenshaw RL, Lyons JP: Fatigue, recovery, and low back pain in varsity rowers. **Med Sci Sports Exerc** 22:463–469, 1990.
27. Scannell JP, McGill SM: Lumbar posture—should it, and can it, be modified? A study of passive tissue stiffness and lumbar position during activities of daily living. **Phys Ther** 83:907–917, 2003.
28. Schaller B: Failed back surgery syndrome: The role of symptomatic segmental single-level instability after lumbar microdiscectomy. **Eur Spine J** 13:193–198, 2004.
29. Weir JP, Housh DJ, Housh TJ, Weir LL: The effect of unilateral eccentric weight training and detraining on joint angle specificity, cross-training, and the bilateral deficit. **J Orthop Sports Phys Ther** 22:207–215, 1995.
30. Wilke HJ, Wolf S, Claes LE, Arand M, Wiesend A: Stability increase of the lumbar spine with different muscle groups. A biomechanical in vitro study. **Spine** 20:192–198, 1995.
31. Yilmaz F, Yilmaz A, Merdol F, Parlar D, Sahin F, Kuran B: Efficacy of dynamic lumbar stabilization exercise in lumbar microdiscectomy. **J Rehabil Med** 35:163–167, 2003.