

## An Intensive, Progressive Exercise Program Reduces Disability and Improves Functional Performance in Patients After Single-Level Lumbar Microdiskectomy

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**Background.** Restoration of physical function following lumbar microdiskectomy may be influenced by the postoperative care provided.

**Objective.** The purpose of this study was to examine the effectiveness of a new interventional protocol to improve functional performance in patients who have undergone a single-level lumbar microdiskectomy.

**Setting.** The study was conducted in physical therapy outpatient clinics.

**Design and Participants.** Ninety-eight participants (53 male, 45 female) who had undergone a single-level lumbar microdiskectomy were randomly allocated to receive education only or exercise and education.

**Intervention and Measurements.** The exercise intervention consisted of a 12-week periodized program of back extensor strength (force-generating capacity) and endurance training and mat and upright therapeutic exercises. The Oswestry Disability Index (ODI) and physical measures of functional performance were tested 4 to 6 weeks postsurgery and 12 weeks later, following completion of the intervention program. Because some participants sought physical therapy outside of the study, postintervention scores were analyzed for both an as-randomized (2-group) design and an as-treated (3-group) design.

**Results.** In the 2-group analyses, exercise and education resulted in a greater reduction in ODI scores and a greater improvement in distance walked. In the 3-group analyses, *post hoc* comparisons showed a significantly greater reduction in ODI scores following exercise and education compared with the education-only and usual physical therapy groups.

**Limitations.** The limitations of this study include a lack of adherence to group assignment, disproportionate therapist contact time among treatment groups, and multiple use of univariate analyses.

**Conclusions.** An intensive, progressive exercise program combined with education reduces disability and improves function in patients who have undergone a single-level lumbar microdiskectomy.

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## Intensive, Progressive Exercise Program for Patients After Single-Level Lumbar Microdiscectomy

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Low back pain continues to be the most prevalent musculoskeletal problem, affecting 70% to 85% of individuals at some time in their lives.<sup>1</sup> One source of low back pain is lumbar disk herniation with resultant sciatica. Cases of sciatica due to lumbar disk herniation that do not resolve with conservative interventions often undergo surgical resection of the herniated material.

Early success rates of lumbar discectomy based on pain, function, and patient satisfaction outcomes range from 65% to 91%.<sup>2-9</sup> These figures show that in 9% to 35% of cases, the postsurgical results are unsatisfactory and patients continue to have symptoms and functional deficits. The success rates reported in these studies may be influenced by the postoperative care provided. In the case of patients with persisting symptoms and disability, additional interventions such as trunk muscle training exercises often are recommended.

The postoperative impairment of trunk muscle performance may explain why the symptoms and functional deficits associated with disk herniation do not fully resolve following the surgical procedure. Due to months of pain and reduced activity prior to surgery, back muscle function may become impaired. In patients with disk herniation, nerve compression and inactivity often result in atrophy, weakness, and greater fatigability of the back extensors.<sup>10-14</sup> Trunk muscles that are weak and more fatigable allow increased stresses on the intervertebral disks, facets, and ligaments.<sup>15</sup> Postoperative muscle atrophy also may result from muscle or nerve damage from the surgical procedure.<sup>13,16</sup>

Previous studies that examined the effectiveness of exercise on patients postdiscectomy conducted training programs ranging from 4 to 12

weeks, with one program lasting 6 months.<sup>17</sup> With the exception of one study that omitted abdominal muscle exercises,<sup>18</sup> most studies included exercises to promote performance of the trunk musculature.<sup>19-24</sup> Most studies described their intervention on the trunk muscles as strengthening or stabilization exercise, whereas 2 studies described their trunk exercises as endurance exercises.<sup>19,23</sup> All exercise programs generally were depicted as being graded and progressive. Some programs included aerobic training,<sup>18,19,24,25</sup> lower-extremity strengthening,<sup>17,18,20,21,23</sup> and trunk or hip flexibility exercises.<sup>19,21,24</sup>

An important goal of physical therapy interventions is to resolve functional deficits associated with low back pain. Previous studies assessed the effectiveness of exercise interventions in resolving functional deficits postdiscectomy primarily by means of self-reported questionnaires.<sup>17-20,22,24</sup> A reduction in disability was reported in 4 studies.<sup>19-22</sup> Physical measures of performance may afford certain advantages over self-reports, but were rarely reported in these studies. A combination of self-report and physical performance measures seems ideal to represent function and disability.

Only one study measured functional performance, and in only one specific task (ie, lifting).<sup>21</sup> In addition,



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with the exception of that study,<sup>21</sup> outcomes have not been assessed earlier than 6 months following surgery. Therefore, the purpose of this study was to examine the early effects of a recently developed intensive postoperative exercise program<sup>26</sup> on self-report and physical performance measures of function and disability in patients who had undergone a single-level lumbar microdiscectomy.

### Method

#### Overall Study Design

This prospective study was divided into 3 phases: a protocol development phase, an implementation or intervention phase, and a follow-up phase. During the protocol development phase, a team of researchers and clinicians developed, tested, and standardized the postsurgical intervention and testing protocols. The protocol development phase, including a detailed presentation of the methods used in the entire project, has already been presented elsewhere.<sup>26</sup>

#### Participants

A total of 176 individuals (100 male, 76 female) between the ages of 18 and 60 years were informed about this study through participating surgeons' offices. These individuals were scheduled to undergo a single-level lumbar microdiscectomy for the first time. Microdiscectomy provides a magnified view of the disk and nerve root, which makes it possible for the surgeon to remove herniated material while minimizing damage to the surrounding tissues. Surgeons screened these patients for presurgical inclusion and exclusion criteria.

As previously reported,<sup>26</sup> the primary presurgical inclusion criteria were diagnosis of disk protrusion confirmed by magnetic resonance imaging testing, predominant symptoms in the lower extremity, radicu-

lar pain distribution, restricted straight leg raise, and positive signs of adverse nerve root tension (ie, impaired mobility, pain, or dysesthesia). An additional inclusion criterion was that the surgery and the 4- to 6-week period after surgery were without an adverse event. There were no enrollment restrictions based on sex, race, or ethnic origin.

Presurgical exclusion criteria included: previous back surgeries, presence of concurrent lower-extremity pathology (other than that associated with low back and lower-extremity pain associated with single-level disk injury), neurological disorders (eg, traumatic brain injury, cerebrovascular accident, seizures), uncontrolled cardiovascular disease, evidence of spinal cord compression, infection, severe respiratory disease, pregnancy, rheumatic joint disease, peripheral vascular disease with sensory loss at the foot, or any condition the participant identified that was considered to limit participation in physical activity. Research personnel further screened them for availability and interest in participating in the study.

The Institutional Review Board of the University of Southern California (USC) granted approval for this randomized controlled trial and its informed consent process. A total of 98 people who satisfied the inclusion and exclusion criteria were enrolled in the study. The participants signed the informed consent form after receiving a detailed explanation of the study.

#### Interventions

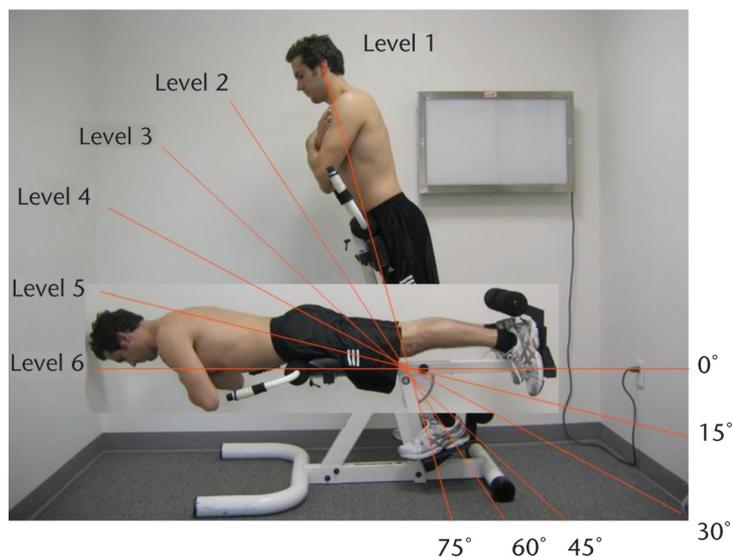
The participants were randomly allocated using blocked randomization to 1 of 2 groups: a group that received one session of back care education (education-only group) or a group that received a back care education session followed by the 12-week USC Spine Exercise Program

(exercise and education group). There were 2 components to this exercise program: (1) back extensor strength (force-generating capacity) and endurance training and (2) mat and upright therapeutic exercises. The education session and the exercise program were implemented by intervention physical therapists at participating physical therapy clinics in the greater Los Angeles area. All intervention therapists received standardized training in implementation of the education session, the exercise protocol, and the method and progression of testing. These intervention therapists passed a videotaped mock testing and intervention session with a score of 90% or more on a checklist of competencies, graded by researchers who developed the interventions, before they administered the interventions to participants.<sup>26</sup>

**Education.** Education comprised a 1-hour, one-on-one session with the intervention therapist that occurred after the preintervention testing session, 4 to 6 weeks after surgery. This educational session was tailored specifically for individuals who had undergone a lumbar microdiscectomy, to help them understand their back problem and how to care for their back. It was guided by an educational booklet that was created especially for this study.<sup>27</sup>

#### Exercise-USC Spine Exercise Program

The exercise program was initiated 2 to 3 days following the education session and occurred 3 times a week for the remainder of the 12 weeks. The USC Spine Exercise Program is unique compared with other therapeutic interventions for patients with back pain in that it is goal oriented, performance based, and periodized, and it was rigorously applied in a standardized manner.<sup>26</sup> It comprised back extensor strength and endurance training and mat and



**Figure 1.** Variable-angle Roman chair. Levels of difficulty of the Roman chair, from easiest (level 1) to most difficult (level 6).

therapeutic exercise training, which were performed concurrently.

The back extensor strength and endurance training portion of the program was designed to load the back extensor muscles in a graded manner by varying the angle at which the trunk was held against gravity, using a variable-angle Roman chair\* (Fig. 1). Exercise session intensity for each week of the program was determined for each individual at the second training session of each week by testing the amount of time he or she was able to maintain the trunk position against gravity (using the variable-angle Roman chair).<sup>26</sup> During the first half of the program, participants trained at 2 levels below their maximum tested level. During the second half of the program, they trained at one level below their maximum tested level, which represented 60% to 80% of the maximum performance of the exercise. These intensities were shown to have the largest increases in strength in a population of health individuals.<sup>28</sup>

\* Backstrong International LLC, 710 N Brea Blvd, Ste G, Brea, CA 92821.

The goal of the program was for participants to be able to maintain a horizontal body position for 180 seconds. This position is equivalent to the Sorensen test position, and the target time reflects Sorensen test performance by adults who were healthy.<sup>29</sup> After an initial 2-week learning phase, participants alternated between phases designed to improve their back extensor strength and their back extensor endurance, starting with a strengthening phase and ending with an endurance phase (Flanagan SP, Kulig K; unpublished research).<sup>26,30</sup>

A team of 20 physical therapists selected exercises for the mat and upright portion of the program and then ranked them according to the physical demand of each exercise. The purpose of the mat and upright therapeutic exercise portion of the program was to progressively and dynamically develop strength, endurance, and control of movement by the trunk and lower-extremity musculature.<sup>26</sup> The number of repetitions was based on a widely accepted continuum for endurance

gains.<sup>31</sup> The number of sets and frequency represented the largest effect size for increases in strength of a population of healthy individuals.<sup>28</sup> Similarly, rest periods and work-to-rest ratios were extracted from a review of the literature for a population of healthy individuals.<sup>32</sup> The systematic and individualized progression or regression of exercise intensity with this protocol complements that of the back extensor strength and endurance training protocol with the variable-angle Roman chair and mimics the clinical decision-making process used by physical therapists.

Three categories of exercises targeting the abdominal, back, and lower-extremity musculature were selected. A progression of these exercises of increasing difficulty was established.<sup>26</sup> The exercises were divided into 3 categories based on performance in supine, quadruped, and standing positions. Each category of exercise included multiple training levels designed to accommodate participants of varying levels of fitness and symptoms and to allow for progression of the workload over the 12-week training period.<sup>26</sup> Participants performed exercises from all 3 categories during the entire intervention period. Levels of difficulty of exercises could vary among the exercise categories for an individual participant.<sup>26</sup> For example, a person could be training the back extensors at a very high level and performing long-duration holds at level 6 of 6 on the variable-angle Roman chair, while only being able to exercise at level 2 of 7 in the abdominal progression.

A testing procedure was developed to determine the appropriate initial training level for each category of exercise and to modify training levels during the training period to allow for progression, regression, or maintenance of exercise intensity

within each category. Test performance was based on each participant's symptoms, use of correct technique, and rate of perceived exertion. The tests were repeated at 3-week intervals during the 12-week intervention.<sup>26</sup> No exercises were performed as part of a home exercise program.

### Outcome Measures

Testing on all outcome measures began 4 to 6 weeks after surgery. All outcome measurements were obtained by evaluators who were blinded to the participants' group allocation. Each evaluator completed standardization training in the testing procedures and passed a videotaped mock testing session with a score of 90% on a checklist of competencies, graded by other research associates, before administering the outcome measures to participants.

The Oswestry Disability Index (ODI) was used to assess the extent to which each participant engaged in activities of daily living. The most recent version of the ODI was used, in which the question regarding sexual activity was replaced with one regarding employment and home-making.<sup>33</sup> Each participant was required to complete the entire questionnaire for it to be considered valid and accepted. The standardized evaluators ensured that all sections were completed during each assessment.

Outcome measures assessing observed performance in activities included the Repeated Sit-to-Stand Test, the 50-Foot Walk Test, and 5-Minute Walk Test. The Repeated Sit-to-Stand Test measured the time (in seconds) needed to complete 5 consecutive repetitions of a sit-to-stand sequence as fast as tolerated. The same type of metal folding chair without armrests was used by each participant. The 50-Foot Walk Test measured the time (in seconds) needed to walk a distance of 50 ft

(15.24 m) as fast as tolerated. The 5-Minute Walk Test measured the distance (in feet) walked in 5 minutes at a self-selected pace. A stopwatch and a tape measure were used for timing and measuring the walking courses, respectively. These measures of functional performance have been shown to be reliable<sup>34,35</sup> and to discriminate individuals with low back pain from individuals who were healthy.<sup>35</sup>

In addition, performance of the back extensor muscles was assessed using a modified Sorensen test (Flanagan SP, Kulig K; unpublished research). This test was derived from the test developed by Biering-Sorensen,<sup>29</sup> who used it to assess the isometric strength and endurance of the lumbar back extensors in individuals without low back pain. The variable-angle Roman chair, used in the exercise intervention, also was used to perform the modified Sorensen test.

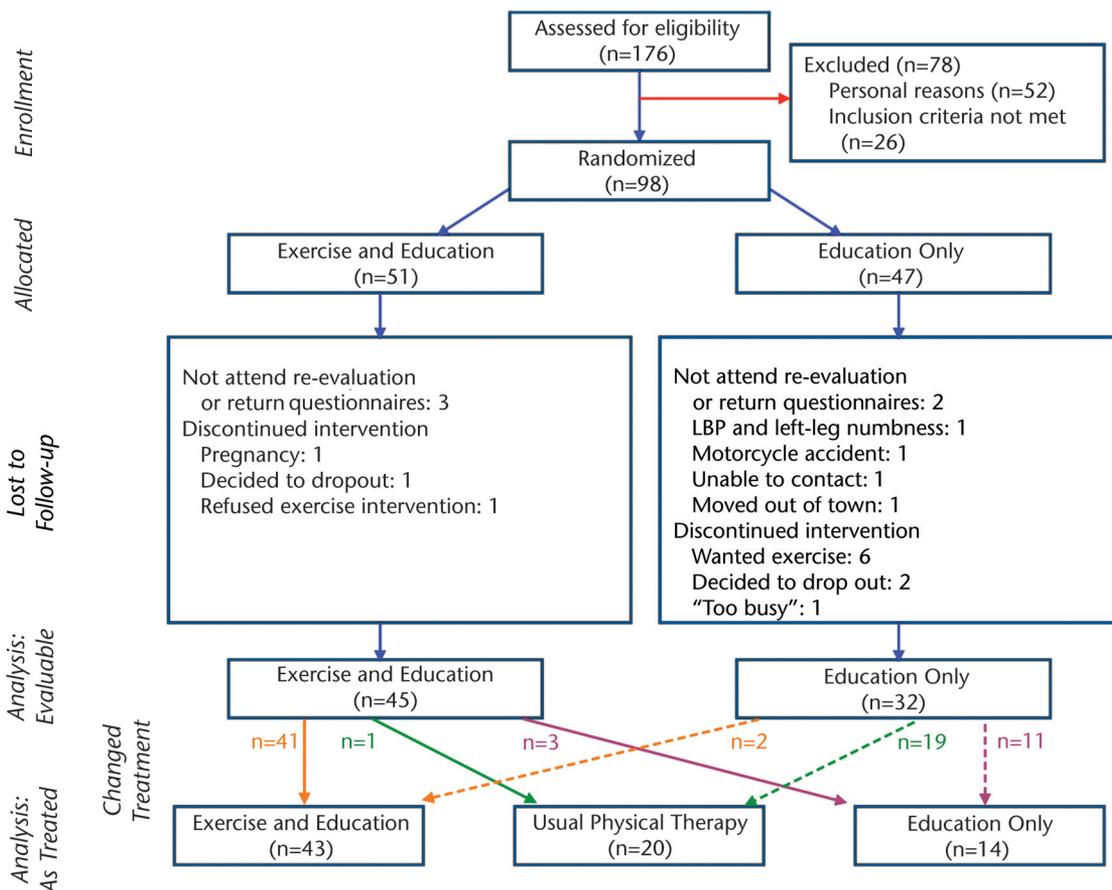
The variable-angle Roman chair, when used in conjunction with a weighted vest, allows the resistance to be progressed from much lighter to much heavier than the original Sorensen test. This apparatus allows the angle of a mobile frame to vary from 75 degrees to 0 degrees relative to the horizontal in 6 increments of increasing difficulty: 75, 60, 45, 30, 15, and 0 degrees (Fig. 1). Each angle was replaced with a level identifier (1, 2, 3, 4, 5, and 6, respectively), with level 6 being the position of the original Sorensen test.<sup>26</sup> The dependent measure for the modified Sorensen test was "impulse," defined as the product of the moment (produced by the mass of the trunk, arms, and head and its lever arm) and the time the body was held at a particular level. All of the tests used as outcome measures in this study have been previously described.<sup>26</sup>

### Research Design

A 2-group, pretest-posttest (repeated-measure) design was planned. Although participants originally were randomly allocated to the 2 groups (education only and exercise and education), not all of the participants adhered to their group allocation. Instead, after their allocation, some of the participants self-selected a course of physical therapy at a clinic of their choosing. This created a third group that we called the "usual physical therapy group." We were unable to control what comprised physical therapy interventions at these nonparticipating clinics (see Appendix for components of these programs), but they were not using the 12-week USC Spine Exercise Program. Therefore, for the purpose of data analyses, we used both a 2-group design (based on the original randomization process) and a 3-group design (based on actual treatment received).

### Sample Size

Power calculations were based on data from prior published studies. These data indicated that the inter-participant variability, with respect to impairment, activity, and participation outcome measures, was moderate to high, suggesting that sample sizes in the range of 40 to 69 participants per group would detect moderate effect sizes. The outcome measures in the current study assessed the immediate effects of the interventions in addition to surgery; thus, the calculations were made on the assumption that the changes due to exercise and education would be greater than those expected for education alone. Accounting for attrition, we determined that a sample size of 50 participants per group would have 80% power to detect a moderate effect size of 0.50 at an alpha level of .05 (one-sided).<sup>26</sup>



**Figure 2.** CONSORT diagram of the MUSSEL randomized clinical trial: number of participants screened, randomized, and retained and analyses. LBP=low back pain.

**Data Analysis**

Hard copies of coded data for all outcome measures and relevant independent measures were transferred by the blinded evaluators to data management and analysis personnel. These data were transferred from hard-copy recordings to a menu-driven Web-based SQL data entry system (PTClinResNet) and then exported to SAS version 8.2<sup>†</sup> for statistical analyses.

Due to a high and disproportionate dropout rate for the follow-up assessments, the analyses were conducted on preintervention and postintervention data only. Consequently, the

<sup>†</sup> SAS Institute Inc, PO Box 8000, Cary, NC 27513.

common method of imputation of missing data became unsuitable, so analyses instead were performed only on those participants (n=77) with follow-up (ie, evaluable) data. For each outcome measure (ODI score, 5-Minute Walk Test, 50-Foot Walk Test, Sit-to-Stand Test), an analysis of covariance (ANCOVA) was performed using the postintervention scores as the dependent variable with the preintervention scores as the covariate. Given the exploratory nature of the study, we elected not to control for type I error. This analysis was conducted on each of the variables for both the 2-group and 3-group designs. For the 3-group design, if the ANCOVA for any of the outcome measures was significant,

*post hoc* testing was performed using the Tukey method to determine statistically significant pair-wise comparisons between the groups.<sup>36</sup> The alpha level for all analyses was set at .05.

**Role of the Funding Source**

This study was funded by a grant from the Foundation for Physical Therapy.

**Results**

**Recruitment and Retention**

A total of 176 patients were screened for randomization (Fig. 2). Seventy-eight of these were excluded for the following reasons: 52 declined to enroll and 26 failed to meet the inclusion criteria. Ninety-eight partici-

pants were randomly allocated using blocked randomization to receive exercise and education (n=51) or education only (n=47). Of the 98 participants, 21 (6 in the exercise and education group and 15 in the education-only group) were inevaluable because they withdrew from the study before completing the 12-week intervention period. In addition, 4 participants in the exercise and education group did not adhere to the group allocation; subsequently, 3 participants received education only and 1 participant sought outside care (usual physical therapy). Furthermore, in the education-only group, 21 participants did not adhere to group allocation; subsequently 2 participants received exercise and education, and 19 participants received usual physical therapy. The participants who remained in the study provided the basis for the evaluable data in 3 groups: exercise and education (n=43), education only (n=14), and usual physical therapy (n=20) (Fig. 2).

Of the 98 randomized participants, the majority were employed, had an income of >\$50,000, and attended at least some college. Overall, 53 (55%) of the participants were men, and the mean ( $\pm$ SD) age was  $40 \pm 10$  years across both sexes. Table 1 summarizes the demographic and clinical characteristics for the 98 randomized participants, stratified by intervention allocations. No statistically significant baseline differences were found among the 3 intervention groups ( $P > .05$ ), nor were significant differences found across the 3 actual intervention groups ( $P > .05$ ) at baseline.

### Postintervention Outcomes

Analyses of evaluable data for the outcome measures for the 2-group allocation are summarized in Table 2. The ANCOVA results revealed a significant difference in the postintervention scores for the ODI

( $P = .001$ ) and the 5-Minute Walk Test ( $P = .024$ ) between the 2 groups, with the improvements exhibited by the exercise and education group approximately twice the magnitude of those seen in the education-only group. The postintervention scores were not significantly different between groups for the 50-Foot Walk Test ( $P = .078$ ) and the Repeated Sit-to-Stand Test ( $P = .430$ ).

Analyses of data for the outcome measures for the actual intervention received are summarized in Table 3. The ANCOVA results revealed a significant difference in ODI scores among groups ( $P = .001$ ). *Post hoc* comparisons showed most improvement in the exercise and education group ( $19.5\% \pm 13\%$ ) compared with both the education-only group ( $9.3\% \pm 11\%$  improvement) ( $P < .016$ ) and the usual physical therapy group ( $7.9\% \pm 11\%$  improvement) ( $P < .003$ ). No significant difference in postintervention scores was found between the education-only and usual physical therapy groups ( $P = .985$ ). Postintervention scores were significantly different among groups for the 5-Minute Walk Test ( $P = .028$ ) and the 50-Foot Walk Test ( $P = .010$ ). The 5-Minute Walk Test *post hoc* comparisons revealed the exercise and education group showed significant improvement ( $293.0 \pm 277$  ft improvement) compared with the usual physical therapy group ( $96.6 \pm 152$  ft improvement) ( $P = .038$ ) but not the education-only group ( $171.4 \pm 316$  ft improvement) ( $P = .188$ ). The 50-Foot Walk Test *post hoc* comparisons showed most improvement in the exercise and education group ( $-1.8 \pm 1.9$  seconds) compared with both the education-only group ( $-1.2 \pm 1.7$  seconds) ( $P = .033$ ) and the usual physical therapy group ( $-0.5 \pm 1.0$  seconds) ( $P = .046$ ). Between-group postintervention scores were not significantly different for the Repeated Sit-to-Stand Test ( $P = .053$ ).

### Performance of the Back Extensors

The exercise and education group was trained and assessed using the same apparatus; therefore, musculoskeletal performance of the back extensors was not included as an outcome measure. However, as a matter of interest, preintervention and postintervention extensor impulse during the modified Sorensen test procedure on a Roman chair was analyzed. In the 2-group analysis (Tab. 4), the ANCOVA results revealed a significant difference in postintervention scores between the 2 groups ( $P < .001$ ). In the analysis of the 3 actual intervention groups (Tab. 5), the ANCOVA results also revealed a significant difference among groups ( $P < .001$ ). *Post hoc* comparisons showed greater improvement in the exercise and education group ( $5,709 \pm 4,577$  N·m·s improvement) compared with both the education-only group ( $860 \pm 3,054$  N·m·s improvement) ( $P < .001$ ) and the usual physical therapy group ( $1,650 \pm 3,002$  N·m·s improvement) ( $P = .003$ ). No significant difference in postintervention scores was found between the education-only and usual physical therapy groups ( $P = .693$ ).

### Adverse Events

Adverse events were monitored and reported according to the protocol approved by the PTClinResNet Safety Monitoring Board.<sup>26</sup> There were 3 adverse events that were considered not related to the study (1 in the exercise and education group and 2 in the education-only group). Adverse events consisted of a second microdiscectomy for unrelenting sciatica, elevated blood pressure, and a severe bout of low back pain and leg numbness.

### Discussion

The purpose of this study was to examine the effectiveness of an interventional protocol<sup>26</sup> to improve

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**Table 1.**

Baseline Demographics, Primary Outcomes, and Participation Measures by Randomization Groups (N=98)<sup>a</sup>

Variable	Exercise and Education Group (n=51)	Education-Only Group (n=47)	P
Demographics			
Age (y)	39.2 (10.2)	41.4 (9.9)	.90
Sex			
Male	29 (58%)	24 (50%)	.43
Latino or Hispanic	6 (12%)	9 (19%)	.35
Race			
Black or African American	1 (2%)	1 (2%)	1.00
White	36 (71%)	33 (70%)	
Unspecified or other	14 (27%)	13 (28%)	
Involved in a litigation process with workers' compensation	4 (9%)	9 (19%)	.14
Medical history			
Duration of pain episode prior to surgery (mo)	6.7 (9.8)	5.9 (7.0)	.66
Time since first onset of low back pain (mo)	82.1 (93.3)	120.7 (125.3)	.12
Time since first onset of sciatica (mo)	33.1 (67.6)	38.7 (69.8)	.71
No. of previous episodes			
<3	13 (32%)	16 (34%)	.75
3-5	3 (7%)	5 (11%)	
5-10	5 (12%)	3 (6%)	
>10	13 (32%)	18 (38%)	
Unspecified	7 (17%)	5 (11%)	
Involved spinal level			
L4/L5	19 (37%)	24 (51%)	.35
L5/S1	31 (61%)	23 (49%)	
L2/L3	1 (2%)	0 (0%)	
Positive passive straight leg raise	29 (63%)	19 (45%)	.09
Oswestry Disability Index (%)	29.4 (15.4)	34.2 (16.2)	.15
Physical function			
5-Minute Walk Test (ft)	1,423.7 (310.6)	1,418.2 (277.1)	.93
50-Foot Walk Test (s)	9.9 (2.8)	9.9 (2.4)	.92
Repeated Sit-to-Stand Test (s)	17.9 (7.7)	18.9 (7.0)	.53
Modified Sorensen test			
Normalized (N·m·s)	5,825.3 (3,432.4)	4,604.9 (3,269.5)	.13

<sup>a</sup> Values are mean ( $\pm$ SD) for continuous variables, frequency (%) for categorical variables. Chi-square tests were used for categorical variables, and one-way analyses of variance were used for continuous variables. Missing data for the following variables (exercise and education group, education-only group): involved in a litigation process with workers' compensation (4, 0), duration of pain episode prior to surgery (10, 0), time since first onset of low back pain (10, 9), time since first onset of sciatica (12, 2), number of previous episodes (10, 0), positive passive straight leg raise (5, 5), physical function (0, 1), modified Sorensen test (2, 3).

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**Table 2.**

Mean Change Score (Postintervention-Preintervention) and 95% Confidence Interval for Each Outcome Measure Based on 2-Group Analyses of Evaluable Data<sup>a</sup>

Outcome Measure	Exercise and Education Group (n=45)	Education-Only Group (n=32)	p <sup>b</sup>
Oswestry Disability Index score (%)	-18.4 (-22.5 to -14.3)	-9.4 (-13.0 to -5.8)	<.001
5-Minute Walk Test (ft)	281.2 (199.1 to 363.3)	133.6 (53.5 to 213.7)	.024
50-Foot Walk Test (s)	-1.7 (-2.2 to -1.2)	-0.9 (-1.5 to -0.3)	.078
Repeated Sit-to-Stand Test (s)	-4.8 (-6.7 to -2.9)	-4.3 (-6.7 to -1.9)	.430

<sup>a</sup> Missing data for the following variables (exercise and education group, education-only group): 5-Minute Walk Test (1, 5), 50-Foot Walk Test (1, 5), and Repeated Sit-to-Stand Test (2, 5).

<sup>b</sup> The P value is a between-group comparison of the postintervention scores using an analysis of covariance (covariate=baseline/pretest).

**Table 3.**

Mean Change Score (Postintervention-Preintervention) and 95% Confidence Interval for Each Outcome Measure Based on Actual Intervention Received<sup>a</sup>

Outcome Measure	Exercise and Education Group (n=43)	Education-Only Group (n=14)	Usual Physical Therapy Group (n=20)	p <sup>b</sup>
Oswestry Disability Index score (%)	-19.5 (-23.4 to -15.6) <sup>c,d</sup>	-9.3 (-15.1 to -3.5)	-7.9 (-12.9 to -2.9)	.001
5-Minute Walk Test (ft)	293.0 (210.1 to 375.9) <sup>d</sup>	171.4 (5.8 to 337.0)	96.6 (29.9 to 163.3)	.028
50-Foot Walk Test (s)	-1.8 (-2.4 to -1.2) <sup>c,d</sup>	-1.2 (-2.1 to -0.3)	-0.5 (-0.9 to -0.1)	.010
Repeated Sit-to-Stand Test (s)	-5.7 (-8.0 to -3.4)	-3.2 (-5.6 to -0.8)	-3.1 (-5.1 to -1.1)	.053

<sup>a</sup> Missing data for the following variables (exercise and education group, education-only group, usual physical therapy group): 5-Minute Walk Test (2, 1, 3), 50-Foot Walk Test (2, 1, 3), and Repeated Sit-to-Stand Test (3, 1, 3).

<sup>b</sup> The P value is a between-group comparison of the postintervention scores using an analysis of covariance (covariate=baseline/pretest).

<sup>c</sup> Significant difference between postintervention scores using analysis of covariance for the exercise and education group and the education-only group from the *post hoc* analysis.

<sup>d</sup> Significant difference between postintervention scores using analysis of covariance for the exercise and education group and the usual physical therapy group from the *post hoc* analysis.

functional outcomes in patients who have undergone a single-level lumbar microdiscectomy. In the 2-group analyses, the exercise and education group showed a significantly greater reduction in ODI scores immediately following the intervention (4.5 months postsurgery). The ODI scores were reduced in both groups, but only reached the level of clinical significance in the exercise and education group.<sup>37</sup>

A Cochrane review of 2002<sup>38</sup> concluded that there is strong evidence that intensive exercise is effective in restoring functional status in patients who have undergone lumbar discectomy. In the studies cited, exercise groups experienced a greater reduction in disability following rehabilitation for single-level lumbar discectomy.<sup>19,20,22</sup> However, there were

several differences among these studies and the current study. The duration of the exercise intervention in these studies ranged from 4 to 8 weeks, whereas the duration of the intervention in the current study was 12 weeks. In addition, assessment time points differed among studies. Of these studies,<sup>19,20,22</sup> only Danielsen et al<sup>20</sup> reported a greater reduction in disability at the first postintervention assessment (6 months postsurgery). A significant reduction was not achieved in the other studies at earlier assessment times following the intervention, but only at follow-up times of 8 months<sup>22</sup> and 12 months<sup>19</sup> postsurgery. In the study by Danielsen et al, subjects who received an 8-week program of vigorous medical exercise therapy had a significantly greater reduction in disability than the control group. How-

ever, in contrast to the current study, Danielsen et al examined the change in disability by subtracting the postintervention disability scores from the preoperative scores. Prior to surgery, subjects in the exercise group had significantly higher disability scores than the control group. Thus, similar within-group changes in disability scores following surgery but prior to the exercise intervention must be assumed in order to conclude that the exercise intervention was responsible for the greater reduction in disability in the exercise group.

Since the Cochrane review,<sup>38</sup> one study has shown a reduction in disability following a postsurgical exercise program in patients who had undergone a single-level lumbar microdiscectomy.<sup>21</sup> In that study, the

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**Table 4.**

Mean Change Score (Postintervention-Preintervention) and 95% Confidence Interval for Back Extensor Impulse Based on 2-Group Analyses of Evaluable Data<sup>a</sup>

Outcome Measure	Exercise and Education Group (n=43)	Education-Only Group (n=26)	<i>p</i> <sup>b</sup>
Modified Sorensen test (N·m·s)	5,328.4 (3,948.6 to 6,708.2)	1,261.1 (1,148.6 to 2,407.4)	<.001

<sup>a</sup> Missing data (exercise and education group, education-only group) for the modified Sorensen test (2, 8).

<sup>b</sup> The *P* value is a between-group comparison of the postintervention scores using an analysis of covariance (covariate=baseline/pretest).

**Table 5.**

Mean Change Score (Postintervention-Preintervention) and 95% Confidence Interval for Back Extensor Impulse Based on Intervention Received<sup>a</sup>

Outcome Measure	Exercise and Education Group (n=43)	Education-Only Group (n=26)	Usual Physical Therapy Group (n=17)	<i>p</i> <sup>b</sup>
Modified Sorensen test (N·m·s)	5,709.6 (4,341.5 to 7,077.7) <sup>c,d</sup>	860.4 (−739.5 to 2,460.3)	1,650.0 (334.2 to 2,965.8)	<.001

<sup>a</sup> Missing data (exercise and education group, education-only group, usual physical therapy group) for the modified Sorensen test (4, 1, 3).

<sup>b</sup> The *P* value is a between-group comparison of the postintervention scores using an analysis of covariance (covariate=baseline/pretest).

<sup>c</sup> Significant difference between postintervention scores using analysis of covariance for the exercise and education group and the education-only group from the *post hoc* analysis.

<sup>d</sup> Significant difference between postintervention scores using analysis of covariance for the exercise and education group and the usual physical therapy group from the *post hoc* analysis.

reduction in ODI scores in the group that received lumbar stabilization exercises was 27%, whereas the reduction in the current study was 18%. This difference may have been due to the difference in baseline ODI scores between the 2 studies. In the study by Yilmaz et al,<sup>21</sup> the initial ODI score was 44%, whereas that of the current study was 31%. The higher baseline level of disability reported by Yilmaz et al may have allotted more potential improvement from their intervention than in the exercise and education group in the current study. The only functional performance measured in that study was lifting. The subjects in the exercise group improved their lifting performance significantly more than those in the control groups.

The exercise intervention in the current study consisted of an intensive, graded strength and endurance training program targeting the trunk and lower-extremity musculature, with the spine maintained in a neutral position. None of the participants in the exercise and education group withdrew due to symptom exacerbation from the intervention. This finding is in agreement with those of other studies,<sup>18,22</sup> indicating that early, intensive training of trunk muscles, initiated 4 to 6 weeks after lumbar diskectomy, can be a safe form of postoperative rehabilitation.

Walking performance was not reported as an outcome measure in previous investigations studying the effects of exercise following lumbar diskectomy. In the 2-group analyses of the current study, the exercise and education group had a significantly greater improvement in 5-minute walk distance compared with the education-only group. The postintervention walking performance of the exercise and education group was similar to values of subjects who were healthy for both measures.<sup>35</sup> This change in walking performance may have been the result of the intensive lower-extremity training performed in the current study. Lower-extremity training was a component of previous exercise protocols following microdiskectomy;<sup>17–20</sup> however, measures of lower-extremity performance were

not reported. A suspected benefit of lower-extremity training was a greater reduction in time to perform the 50-Foot Walk Test and the Repeated Sit-to-Stand Test. However, the time reduction of both tests in the exercise and education group was not significantly greater than that of the education-only group, which suggests a less-discriminating role for these tests.

A unique comparison in our study was the analysis of the actual interventions received. Participants who opted out of their allocated intervention group to pursue physical therapy outside of the study agreed to remain in the study, allowing for inclusion of a third group in the analyses. The participants who received usual physical therapy care attended local physical therapy clinics where their intervention was determined by their physical therapists, rather than the USC Spine Exercise Program. The results of the analysis of the actual intervention received (3-group analysis) showed a greater improvement in performance of the exercise and education group. The

not reported. A suspected benefit of lower-extremity training was a greater reduction in time to perform the 50-Foot Walk Test and the Repeated Sit-to-Stand Test. However, the time reduction of both tests in the exercise and education group was not significantly greater than that of the education-only group, which suggests a less-discriminating role for these tests.

improvement in ODI scores, 5-minute walk distance, and 50-foot walk time was significantly greater in those participants who received exercise and education compared with either the education-only group or the usual physical therapy group. These results suggest greater effectiveness of the current exercise program in reducing disability and improving walking performance than that expected from usual physical therapy. The volume and intensity of the interventions in the usual physical therapy group were lower than those of the USC Spine Exercise Program, perhaps reflecting caution when managing postsurgical cases. Inherent in the usual physical therapy group is a lack of standardized care procedures, resulting in high variability in both the durations and types of interventions received. The lack of standardization of care in the usual physical therapy group may have influenced the results.

One limitation of this study was the large number of participants who chose not to adhere to the original allocation into the education-only group. This finding suggests that more participants preferred exercise as part of their intervention rather than education only. A selection bias of the participants can confound the interpretation of the results. For instance, more highly motivated participants in the education-only group may have withdrawn from the study, which may have led to poorer outcomes in that group. The intention-to-treat analysis is a strategy used to deal with participants who withdraw from a study. One common form of intention-to-treat analysis is the imputation of missing data by carrying the last observation forward. If applied to the current study, the preintervention score would be used again as the postintervention score. Because of the greater drop-out rate in the education-only group, this analysis would clearly bias the

results in favor of the exercise and education group. Analysis of the evaluable data in the 2-group analysis resulted in more-conservative results, in that no data were carried forward from baseline and some participants received exercise in physical therapy clinics outside the study.

A second limitation is that the exercise and education group received substantially more time with a physical therapist compared with the other groups. More time with the therapist may have influenced the measured outcomes. However, it should be noted that such time inequalities may not necessarily influence disability outcome measures. Three previous studies of intervention effects on disability from low back problems with disparate intervention durations showed no differences in the reduction in disability between these groups, although patient satisfaction was higher in the group that received more therapist attention.<sup>39-41</sup>

A third limitation involves the statistical analyses. Univariate analyses were performed on each of the outcome variables. As the multiple use of a univariate analysis raises the risk of a type I error, the results should be viewed with this fact in mind.

### Conclusion

The outcome of microdiscectomy for a lumbar disk herniation depends on the postoperative regimen offered. An intensive 12-week strength and endurance training program of the trunk and lower-extremity musculature is safe and results in a greater reduction in disability and a greater increase in walking performance immediately following the intervention. Because only the immediate effects of the exercise program were reported, long-term effects cannot be assumed.

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References

- 1 Andersson GB. Epidemiological features of chronic low-back pain. *Lancet*. 1999;354:581-585.
- 2 Asch HL, Lewis PJ, Moreland DB, et al. Prospective multiple outcomes study of outpatient lumbar microdiscectomy: should 75% to 80% success rates be the norm? *J Neurosurg*. 2002;96:34-44.
- 3 Davis GW, Onik G. Clinical experience with automated percutaneous lumbar discectomy. *Clin Orthop Relat Res*. 1989;(238):98-103.
- 4 Findlay GF, Hall BI, Musa BS, et al. A 10-year follow-up of the outcome of lumbar microdiscectomy. *Spine*. 1998;23:1168-1171.
- 5 Goldstein TB, Mink JH, Dawson EG. Early experience with automated percutaneous lumbar discectomy in the treatment of lumbar disc herniation. *Clin Orthop Relat Res*. 1989;(238):77-82.
- 6 Maroon JC, Onik G, Sternau L. Percutaneous automated discectomy: a new approach to lumbar surgery. *Clin Orthop Relat Res*. 1989;(238):64-70.
- 7 Loupasis GA, Stamos K, Katonis PG, et al. Seven- to 20-year outcome of lumbar discectomy. *Spine*. 1999;24:2313-2317.
- 8 Weinstein JN, Tosteson TD, Lurie JD, et al. Surgical vs nonoperative treatment for lumbar disk herniation—the Spine Patient Outcomes Research Trial (SPORT): a randomized trial. *JAMA*. 2006;296:2441-2450.
- 9 Osterman H, Seitsalo S, Karppinen J, Malmivaara A. Effectiveness of microdiscectomy for lumbar disc herniation: a randomized controlled trial with 2 years of follow-up. *Spine*. 2006;31:2409-2414.
- 10 Barker KL, Shamley DR, Jackson D. Changes in the cross-sectional area of multifidus and psoas in patients with unilateral back pain: the relationship to pain and disability. *Spine*. 2004;29:E515-E519.
- 11 Mayer TG, Mooney V, Gatchel RJ, et al. Quantifying postoperative deficits of physical function following spinal surgery. *Clin Orthop Relat Res*. 1989;(244):147-157.
- 12 Dedering A, Harms-Ringdahl K, Nemeth G. Back extensor muscle fatigue in patients with lumbar disc herniation: pre-operative and post-operative analysis of electromyography, endurance time and subjective factors. *Eur Spine J*. 2006;15:559-569.
- 13 Rantanen J, Hurme M, Falck B, et al. The lumbar multifidus muscle five years after surgery for a lumbar intervertebral disc herniation. *Spine*. 1993;18:568-574.
- 14 Yoshihara K, Nakayama Y, Fujii N, et al. Atrophy of the multifidus muscle in patients with lumbar disk herniation: histochemical and electromyographic study. *Orthopedics*. 2003;26:493-495.
- 15 Dolan P, Adams MA. Repetitive lifting tasks fatigue the back muscles and increase the bending moment acting on the lumbar spine. *J Biomech*. 1998;31:713-721.
- 16 Sihvonen T, Herno A, Paljarvi L, et al. Local denervation atrophy of paraspinal muscles in postoperative failed back syndrome. *Spine*. 1993;18:575-581.
- 17 Donaldson BL, Shipton EA, Inglis G, et al. Comparison of usual surgical advice versus a nonaggravating six-month gym-based exercise rehabilitation program post-lumbar discectomy: results at one-year follow-up. *Spine J*. 2006;6:357-363.
- 18 Choi G, Raiturker PP, Kim MJ, et al. The effect of early isolated lumbar extension exercise program for patients with herniated disc undergoing lumbar discectomy. *Neurosurgery*. 2005;57:764-772; discussion 764-772.
- 19 Dolan P, Greenfield K, Nelson RJ, Nelson IW. Can exercise therapy improve the outcome of microdiscectomy? *Spine*. 2000;25:1523-1532.
- 20 Danielsen JM, Johnsen R, Kibsgaard SK, Hellevik E. Early aggressive exercise for postoperative rehabilitation after discectomy. *Spine*. 2000;25:1015-1020.
- 21 Yilmaz F, Yilmaz A, Merdol F, et al. Efficacy of dynamic lumbar stabilization exercise in lumbar microdiscectomy. *J Rehabil Med*. 2003;35:163-167.
- 22 Manniche C, Skall HF, Braendholt L, et al. Clinical trial of postoperative dynamic back exercises after first lumbar discectomy. *Spine*. 1993;18:92-97.
- 23 Johannsen F, Remvig L, Kryger P, et al. Supervised endurance exercise training compared to home training after first lumbar discectomy: a clinical trial. *Clin Exp Rheumatol*. 1994;12:609-614.
- 24 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*. 2001;72:518-524.
- 25 Brennan GP, Shultz BB, Hood RS, et al. The effects of aerobic exercise after lumbar microdiscectomy. *Spine*. 1994;19:735-739.
- 26 Selkowitz DM, Kulig K, Poppert EM, et al. The immediate and long-term effects of exercise and patient education on physical, functional, and quality-of-life outcome measures after single-level lumbar microdiscectomy: a randomized controlled trial protocol. *BMC Musculoskelet Disord*. 2006;7:70.
- 27 Physical Therapy Clinical Research network (PTClinResNet). Available at: <http://pt.usc.edu/clinresnet/>.
- 28 Rhea MR, Alvar BA, Burkett LN, Ball SD. A meta-analysis to determine the dose response for strength development. *Med Sci Sports Exerc*. 2003;35:456-464.
- 29 Biering-Sorensen F. Physical measurements as risk indicators for low-back trouble over a one-year period. *Spine*. 1984;9:106-119.
- 30 Flanagan SP, Kulig K. Assessing musculoskeletal performance of the back extensors following a single-level microdiscectomy. *J Orthop Sports Phys Ther*. 2007;37:356-363.
- 31 Kraemer WJ, Adams K, Cafarelli E, et al. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. *Med Sci Sports Exerc*. 2002;34:364-380.
- 32 Willardson JM. A brief review: factors affecting the length of the rest interval between resistance exercise sets. *J Strength Cond Res*. 2006;20:978-984.
- 33 Fritz JM, Irrgang JJ. A comparison of a modified Oswestry Low Back Pain Disability Questionnaire and the Quebec Back Pain Disability Scale. *Phys Ther*. 2001;81:776-788.
- 34 Harding VR, Williams AC, Richardson PH, et al. The development of a battery of measures for assessing physical functioning of chronic pain patients. *Pain*. 1994;58:367-375.
- 35 Simmonds MJ, Olson SL, Jones S, et al. Psychometric characteristics and clinical usefulness of physical performance tests in patients with low back pain. *Spine*. 1998;23:2412-2421.
- 36 Portney LG, Watkins MP. *Foundations of Clinical Research: Applications to Practice*. Englewood Cliffs, NJ: Prentice-Hall; 2000.
- 37 Ostelo RW, de Vet HC. Clinically important outcomes in low back pain. *Best Pract Res Clin Rheumatol*. 2005;19:593-607.
- 38 Ostelo RW, de Vet HC, Waddell G, et al. Rehabilitation after lumbar disc surgery. *Cochrane Database Syst Rev*. 2002;4:CD003007.
- 39 Niemisto L, Rissanen P, Sarna S, et al. Cost-effectiveness of combined manipulation, stabilizing exercises, and physician consultation compared to physician consultation alone for chronic low back pain: a prospective randomized trial with 2-year follow-up. *Spine*. 2005;30:1109-1115.
- 40 Frost H, Lamb SE, Doll HA, et al. Randomised controlled trial of physiotherapy compared with advice for low back pain. *BMJ*. 2004;329:708.
- 41 Pengel LH, Refshauge KM, Maher CG, et al. Physiotherapist-directed exercise, advice, or both for subacute low back pain: a randomized trial. *Ann Intern Med*. 2007;146:787-796.

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### Appendix.

Characteristics of Usual Physical Therapy Care Received by the Participants Who Elected to Pursue Care Outside of the MUSSEL Project

Characteristics of Clinical Physical Therapy Visits	Mode	Range	Percentage
No. of visits attended	12	1–24	
Frequency of visits (per week or per month)	3/wk	3/wk to 1/mo	
Time in session (min)	45	30–120	
Main reason for discontinuing care (% of total participants)			25 met physical therapy goals 22 self-discharge 15 insurance “ran out” 38 other (plateau, no reason given)
Type of intervention			
Education			100
Modalities (ice, heat, electrotherapy)			100
Stabilization exercises			100
Stretching			80
Manual therapy			40
Exercise with back equipment			30