SPINE Volume 31, Number 18, pp E611–E620
©2006, Lippincott Williams & Wilkins, Inc.

Control of the Lumbar Neutral Zone Decreases Low Back Pain and Improves Self-Evaluated Work Ability

A 12-Month Randomized Controlled Study

Jaana Suni, PT, PhD, Marjo Rinne, PT, MSci, Antero Natri, MD, DMSci,
Matti Pasanen Statistisian, MSci, Jari Parkkari, MD, DMSci,
and Hannu Alaranta, MD, DMSci

Study Design. A randomized controlled study with 12 months intervention.

Objective. To study the effectiveness of a training intervention with emphases on the control of lumbar neutral zone (NZ) and behavior modeling as secondary prevention of low back pain (LBP) and disability.

Summary of Background Data. Improving the control of lumbar NZ and enhancing muscle activation patterns ensuring spinal stability have been proposed as means for secondary prevention of LBP and disability. In addition, cognitive behavior interventions have been shown to lower the risk of recurrence of LBP and long-term disability.

Methods. Middle-aged working men with recent LBP but without severe disability were randomly allocated to either a training (TG, n = 52) or control group (CG, n = 54). The aim was to exercise twice a week for 12 months, once guided and once independently. The outcome measures were the changes in intensity of LBP, disability, self-evaluated future work ability, and neuromuscular fitness.

Results. The intensity of LBP decreased significantly more (39%) in the TG than in CG at 12 months. The proportion of subjects with negative expectations about their future work ability decreased in both groups at 6 and 12 months; however, the proportion was significantly bigger in TG compared with CG ($P = 0.028$). There effects on disability indexes and fitness were not statistically significant.

Conclusions. Controlling lumbar NZ is a specific form of exercise and daily self-care with potential for prevention of recurrent nonspecific LBP and disability among middle aged working men.

Key words: recurrent low back pain, secondary prevention, lumbar neutral zone, spinal stability, neuromuscular training, behavior modeling. **Spine 2006;31:E611–E620**

A single episode of acute low back pain (LBP) has a favorable natural history with respect to pain reduction, functional ability, and work capacity.[1] The course of LBP for most primary care patients, however, is recurrent rather than acute or chronic. Recurrence rates are high ranging from 60% to 86%, particularly in the first year after the acute episode.[2] The mechanism between LBP and associated changes leading to recurrent episodes and eventually to chronic disability are not fully understood. Recent findings underscore the significance of early intervention that specifically aim to prevent chronic problems.[3]

Changes in motor control and function of the trunk muscles have been reported frequently in patients with LBP.[4–8] There is growing evidence that disorders do exist where movement and motor control impairments appear as a result of abnormal tissue loading and pain.[9–11] In addition, psychologic processes such as stress, fear, anxiety, and depression are known to disrupt motor behavior.[8] The consequences of these changes are potential factors in the recurrence of LBP.[8]

Biomechanical research has strengthened the current understanding of mechanisms of low back injury and pain as well as muscle activation patterns in relation to lumbar spinal stability and loading. Briefly, controlling the neutral zone (NZ) of lumbar motion (*i.e.*, preserving normal low back curve similar to that of upright standing) and avoiding full lumbar flexion appear to provide protection from ligament injury and posterior disc herniation.[9,12,13] Cocontraction of the torso muscles is necessary for maintaining stability around a NZ,[14–16] the main stabilizers continually changing as the task changes. When the spine is flexed in the end range of motion, the lumbar extensor muscles lose their ability to assist with anterior shear stability, which in turn increases the risk of injury.[17]

The contemporary strategies for rehabilitation of individuals with LBP[18–21] are consistent with aforepresented findings on LBP induced impairments. However, only few randomized controlled interventions applying these strategies have been reported so far.[22–25]

Resent research findings have also demonstrated that cognitive-behavior interventions can lower the risk of long-term disability developing.[3,26,27] This approach has also been part of exercise interventions with successful outcomes.[24,28] Thus, one focus of interventions targeted to prevent recurrent and long-term LBP and disability should be to change patients' behavior and beliefs about LBP and its management so that they can better cope with their problems.

From the UKK Institute, Tampere, Finland.
Acknowledgment date: December 1, 2005. First revision date: February 1, 2006. Second revision date: March 1, 2006. Acceptance date: March 27, 2006.
Supported by the Finnish Work Environment Fund and the Medical Research Fund of Tampere University Hospital.
The manuscript submitted does not contain information about medical device(s)/drug(s).
Foundation funds were received in support of this work. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.
Address correspondence and reprint requests to Jaana Suni, PT, PhD, UKK Institute, Kaupinpuistonkatu 1, 33500 Tampere, Finland; E-mail: jaana.h.suni@uta.fi

The aim of this study was to investigate the effects of a 12-month neuromuscular training and counseling intervention (NTCI), with emphases on the control of lumbar NZ and behavior modeling, on LBP and disability, work ability, and neuromuscular fitness in middle-aged men.

■ Materials and Methods

Secondary prevention of recurrent LBP is of great importance to the Finnish Railroad, VR-Group Ltd. (FR) because more than 75% of the workers experience LBP at some point of their career. The proposed NTCI was developed to be used for these purposes in the FR.

Design. The study was carried out as a randomized controlled trial of NTCI in 3 different workplace localities. Assessments were conducted at baseline, after 6 months and 12 months at a research institute in Tampere. After the baseline assessments, the participants were randomly allocated to either training group (TG) or control group (CG), separately for each locality according to a computer-generated randomization list.

Subjects. The subjects were recruited on the basis of a former screening of musculoskeletal symptoms. In May 2002, a questionnaire[29] was sent to all of the workers of the FR in the western area of Finland (n = 1,995) by their occupational healthcare unit. Sixty-five percent of the workers (n = 1,290) answered, and 585 of them were interested in participating in the study. Of those, men meeting the criteria for participation were invited to the study and 106 of them participated in the baseline assessments. There were 52 men in TG and 54 in CG after the randomization. The inclusion criteria for participation, study flowchart, and participation rates at different stages of the study are presented in Figure 1.

All study subjects gave their written consent to participate after being informed about the possible risks and benefits of the study. They were encouraged to continue their usual physical activity. They also knew that the CG was invited to participate in the NTCI after the 12 months in exactly the same manner as the TG. Approval for the study protocol was received from the Ethical Committee of Pirkanmaa Hospital District on the December 13, 2001.

Intervention. The intervention included neuromuscular training and counseling with cognitive-behavioral learning goals for improved movement patterns (*i.e.*, better control of the lumbar NZ and lumbar stability[10]) in daily life. The conceptual background of exercises and emphasis on the control of lumbar NZ was based on the biomechanical approach (*i.e.*, harmful loading is the cause of tissue damage which causes pain, which at first induces changes in motor control and later in musculoskeletal structures). The other framework was the cognitive-behavior model (*i.e.*, changing attitude toward the reasons for LPB, and increasing personal knowledge, understanding, and physical skills to better manage current LPB and prevent future episodes).

The target for the subjects in TG was to exercise twice a week for 12 months, once guided by physical therapists (PT) and once independently. The training program consisted of 10 exercises. The rationale, order, dosage, and progression for the exercises are given in Table 1. Illustrations of the 10 exercises are provided in Figure 4. The subjects were provided with a training book including information on lumbar NZ and instructions and pictures for all exercises and training log sheets for recording the dosage of each exercise at each exercise session (ES). Subjects missing more than two guided ES or not returning the log sheet for a month were contacted by the PT by phone and encouraged to continue the training and to return the log sheets.

The PT guiding ES were also responsible for giving systematic counseling on the principles and practical

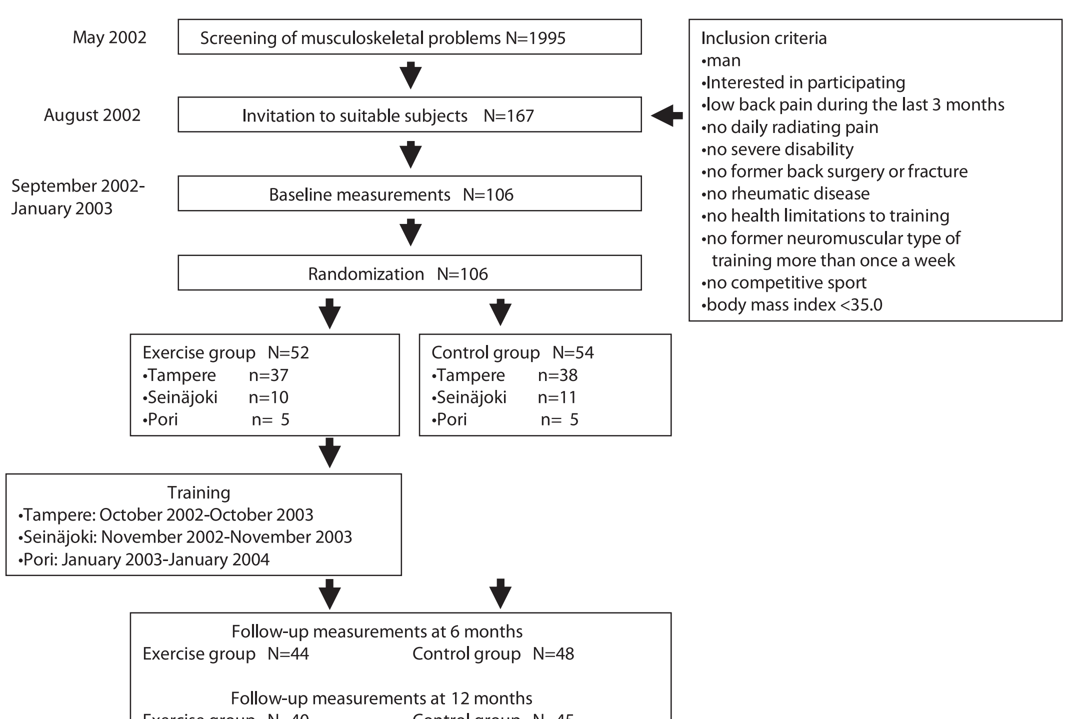

Figure 1. Inclusion criteria for the study, study flowchart and participation rates at different stages.

Table 1. Rationale for the Neuromuscular Exercise Program, the Order and Dosage of Each Exercise, and the Learning Goal and Contents of the Counseling Process at Different Stages of the Intervention

Rationale for the Exercise Program

To increase spinal stability[10,14] by
- Improving the motor control of the muscles stabilizing the lumbar spine
- Using exercises that minimize the load (compressive, shear) on the spinal structures but induce high activity level and Co-contraction of the trunk muscles (McGill *et al* 1996, Juker *et al* 1998)
- Enhancing the endurance of the trunk muscles

To build movement patterns that help to avoid end-range flexion movement of the lumbar spine[10] by
- Improving the control of NZ in upright positions (McGill and Kippers 1994, McGill 1997)
- Emphasizing the 1-leg performances (McGill 2002)
- Increasing the flexibility of the hip joints (Dolan and Adams 1993)

To decrease the risk of harmful lumbar rotation (Adams *et al* 2003) by
- Improving the motor control of NZ
- Emphasizing the 1-leg performances
- Increasing the rotational mobility of the thoracic spine

Exercise	Dosage
1) Balance exercises with a stick while standing on one leg	40 rep. (2 × 10 + 10 rep.) with alternating legs
2) Abdominal curl-up exercise with slight rotation	1–2 × 6 + 6 rep. for both sides
3) Flexibility exercise for hip joints, "the ski-jumper stretch"	3–5 × 20 seconds stretch
4) Squat exercise with a stick standing on	
2 legs or	1–2 × 10–15 rep. on 2 legs;
1-leg	1–2 × 8–12 rep. on both right and left leg
5) Horizontal side-support*	
Stage 1 and 2	8–12 rep. with 5 seconds hold for both sides
Stage 3	8–12 circles with 5 seconds hold for each position
6) Stretching exercise for hip flexors	3–5 × 20 seconds stretch
7) Balance and trunk muscle exercise on hands and knees*	8 + 8 rep. with 10 seconds hold for both sides
8) Stretching exercise for knee flexors	2–3 × 30 seconds stretch for both legs
9) Upper body rotation with a rubber band, "sawing"	1–2 × 8–12 rep. for both sides
10) Upper body rotation while side-lying, "yoga stretch"	1 × 60 seconds for both sides

The Learning Goal and Contents of the Counseling Process at Different Stages of the Intervention

Stage 1 (0–6 months):
Learning goal: To be able to perform each exercise with a proper control of lumbar neutral zone (NZ).
- Personal guidance to ensure a proper skill and exertion level of each exercise
- Knowledge on the importance of each exercise for functional ability of the back
- Knowledge on the loading characteristics of each exercise on low back
- Personal guidance to enhance the learning of correct performance technique of each exercise with emphases on controlling the lumbar NZ

Stage 2 (7–9 months)
Learning goal: To be able to consciously apply the principle of lumbar NZ to daily activities at work and during leisure-time.
- Counseling on the advantages of 1-leg performances in the control of lumbar NZ in daily activities like lifting, squatting and stooping, and personal guidance on how to perform these activities in daily life
- Knowledge on the importance of the control of lumbar NZ in daily activities during the first 2–3 hours after waking up

Stage 3 (10–12 months)
Learning goal: To be motivated to take care of the wellness of one's back in the future.
- Discussions with PT on the possible difficulties in controlling the lumbar NZ at work and during leisure-time
- Discussions with PT on how to improve the control of lumbar NZ in work tasks or other activities that are potentially harmful to the back

*According to McGill 2001.
Rep. indicates repetitions.

applications of the control of lumbar NZ. A detailed description of the aims and content of the counseling process is given in Table 1. The neuromuscular exercises were the means to teach the skill of controlling the lumbar neutral zone in different positions and tasks. The PT taught and demonstrated how to avoid complete lumbar flexion and how to activate the lumbar extensor muscles by hip flexion. The learning goal for the first 6 months was to be able to control the lumbar NZ in all exercises. During the last 6 months, the PT introduced the advantages of one-leg performances[10] and gave personal guidance on how to apply the new skills, learned in neuromuscular training, to all kinds of activities of daily life. The learning goal was the control lumbar NZ in all daily activities during work and leisure time.

Assessments. The personnel conducting the assessments were blinded to the subjects' study group and were not involved in the intervention. Assessments at baseline, 6 months, and 12 months included self-ratings of LBP and disability [Visual Analog Scale (VAS) for past 7 days, VAS for past 2 months[30,31] Oswestry Disability Index (ODI),[30,32,33] Pain and Disability Index (PDI)[34–36]], and a questionnaire on musculoskeletal symptoms,[29] including self-evaluation of work ability within the next 5 years with

Table 2. Characteristics of the Subjects at Baseline

	Training Group			Control Group		
	Mean	(SD)	n	Mean	(SD)	n
Age	47.6	(5.8)	52	46.9	(5.3)	54
Body mass index	27.1	(3.7)	52	27.4	(3.7)	54
Blood pressure						
Diastolic*	86.4	(8.8)	52	88.3	(9.3)	54
Systolic*	132.1	(15.6)	52	134.8	(14.7)	54
Perceived general health status		%	n		%	n
Poor		4	2		7	4
Average		69	36		63	34
Good		27	14		30	16
		100	*52*		*100*	*54*
Frequency of low back pain during the last 3 months						
Not in any day		11	6		6	3
In 1–7 d		48	25		40	21
In 8–30 d		27	14		36	19
In more than 30 d, but not daily		11	6		9	5
Daily		2	1		9	5
		100	*52*		*100*	*53*
Occupation						
Engine driver, conductor		62	32		50	27
Assembler, workman		34	18		30	16
Superior, foreman		4	2		20	11
		100	*52*		*100*	*54*
Occupational physical exertion						
Heavy (lifting, carrying, etc.)		8	4		11	6
Moderate		46	24		53	29
Light (office work)		46	24		36	19
		100	*52*		*100*	*54*
Vibration at work						
Yes		55	28		57	23
No		45	23		53	30
		100	*51*		*100*	*53*
Smoking during the last 6 months						
Yes		29	15		39	21
No		71	37		61	33
		100	*52*		*100*	*54*
Leisure-time physical activity (brisk)						
<1/wk		46	24		44	24
1–2/wk		48	25		44	24
≥3/wk		6	3		11	6
		100	*52*		*100*	*54*

*Average of 2 following measurements after 5 minutes rest (sitting).

reference to musculoskeletal health (rating 1 = probably no difficulties in coping with work; 2 = difficulties may appear in coping with work; 3 = difficulties are likely to appear in coping with work).

In addition, assessment of neuromuscular fitness, including pretesting health screening,[37] was conducted with standard methods.[38,39] The selected tests measured static balance (one leg stand), dynamic balance (backwards walking, running figure of eight), trunk side-bending flexibility, hamstring muscle extensibility, dynamic endurance of abdominal and hip flexor muscles (abdominal curl with rotation, sit-up), and upper body strength and ability to stabilize the back (modified push-ups). Details of the fitness measurements are shown elsewhere[38,39] and are given by the corresponding author on request.

All of the participants were asked to keep a structured diary on their weekly leisure-time physical activity and work commuting[40] during the whole 12-month intervention. In addition, the TG filled in a questionnaire on their experiences of neuromuscular training at 6 and 12 months.

The primary outcome measures were the changes in intensity of LBP, disability indexes, self-evaluated work ability, and neuromuscular fitness. In addition, training adherence (compliance to exercise according to log sheets, participation in guided ES) and training experiences of the TG are reported as outcomes for safety and feasibility of the proposed intervention.

Statistical analyses. Preceding the study, the sample size and power calculation were done for LBP and disability outcome variables; that is, for VAS, PDI, and ODI. Using an α level of 0.05 and estimated standard deviation calculated on the basis of previous cross-sectional data,[33,36] a sample size of 40 men in each group gave 80% power for the study to detect following differences in change between TG and CG: 12 mm in VAS, 5 points in PDI, and 6 points in ODI.

Percentages and means with standard deviations (SD) or median with minimum and maximum values were used as descriptive statistics. Because of skewed distributions, log transformation of LBP and disability variables were used in the analysis. Median with minimum and maximum scores or geometric means (transformation of logs back to the original scale)

Table 3. Descriptive Baseline Data of Variables Used as the Primary Outcome Measures of the Study

	Training Group Median	Training Group (Minimum, Maximum)	n	Control Group Median	Control Group (Minimum, Maximum)	n
VAS, past 7 d (0–100)	11.5	(0, 92)	52	13.5	(0, 62)	54
VAS, past 2 mos (0–100)	20.0	(0, 100)	52	22.5	(0, 99)	54
ODI (0–50)	5.5	(2, 19)	52	5.0	(0, 13)	54
PDI (0–70)	5.0	(1, 38)	52	6.0	(0, 22)	54
Self-estimated Work Ability Within the Next 5 Years With Reference to Musculoskeletal Health*						
		%	n		%	n
Probably no difficulties in coping with work		28	14		31	17
Difficulties in coping with work may appear		60	30		56	30
Difficulties in coping with work are likely to appear		12	6		13	7
Total		100	50		100	54
Neuromuscular Fitness, Proportion of Subjects with Low Fitness†						
		%	n/N		%	n/N
Balance and agility						
1-leg standing		31	19/52		22	12/54
Backwards walking		31	16/52		35	18/52
Running figure of 8		29	15/51		31	17/54
Flexibility						
Trunk side-bending		79	41/52		70	38/54
Hamstring muscle extensibility†		91	40/44		79	37/47
Muscular strength and endurance						
Dynamic sit-up		11	6/52		13	7/54
Curl-up with rotation		22	10/45		21	10/47
Modified push-ups		57	28/49		53	28/53

*Assessed in the prescreening of the study (May 2002).
†Low fitness according to a former population study by Suni *et al* 1999.
VAS indicates Visual Analog Scales; ODI, Oswestry Disability Index; PDI, Pain and Disability Index.

at baseline and at 6 and 12 months were given as descriptive statistics for the measures of LBP and disability. Analysis of covariance with log transformed variables was used to test the between-group differences of changes in the outcomes of LBP and disability. Geometric mean ratios and their 95% confidence intervals (CI) adjusted for the baseline measures were calculated as anti-logs of the differences in group means at 6 months and 12 months.

Logistic regression analyses, adjusted for differences in baseline distributions, were used in estimating the odds ratios (with 95% CI) of subjects with negative expectations for self-evaluated work ability and low neuromuscular fitness between TG and CG at 6 and 12 months. The criterion of low fitness was based on percentile values (lowest 40%) of men of similar age in a former population study.[41]

All analyses were performed on an intention-to-treat basis. Subjects were excluded from the intention-to-treat analysis only if endpoint data were not available. In all tests, P values less than 5% (<0.05) were considered statistically significant. All analyses were conducted using SPSS software, version 12.0.1 (SPSS INC, Chicago IL).

Results

Study Sample

The characteristics of the study subjects in TG and CG are given in Table 2. A majority of the men perceived their general health as average (66%). All of the men invited to the study reported LBP at the time of the prescreening (Figure 1); however, 4 to 8 months later, 8% had not experienced LBP during the past 3 months. Many of the proposed risk factors for LBP (*i.e.*, continuous vibration, heavy physical work, regular smoking, and physical inactivity) were common among the study population. There were more engine drivers and conductors (62% *vs.* 50%), and less superior and foreman (4% *vs.* 20%) among the TG compared with the CG. The descriptive baseline data of the main outcome measures of the study is given in Table 3 and is referred to in the discussion.

Dropouts, Exercise Adherence, and Training Experiences

Of the 106 participants, 8 men in TG and 6 in CG dropped out during the first 6 months of the intervention, and 4 and 3 more during the last 6 months, respectively. The group specific reasons for dropping out of the study are given in Table 4.

Exercise compliance during the first 6 months was fair but became poorer during the last 6 months. Detailed descriptions of exercise adherence and participation in guided ES are given in Table 4. All the men in TG answering the questionnaire on training experiences at 6 months (n = 41) felt they had enough guidance and counseling, 90% or more felt they can perform the exer-

Table 4. Reasons for Dropping Out of the Study in the Training and Control Group. The Exercise Adherence (Compliance) of the Training Group

The Reasons for Dropping Out of the Study			
Training Group, n = 52	(n)	Control Group, n = 54	(n)
Working at different locality or traveling	(4)	Working at different locality or traveling	(3)
Not willing	(1)	Not willing	(3)
Bulging of the disc	(1)	Back pain	(1)
Upper extremity problems	(3)	Surgery of the shoulder	(1)
Problems at home	(2)	Retired	(1)
Not known	(1)		
Total	(12)	Total	(9)

Compliance 6 Months, Training Group

	Self-kept Exercise Diary			Guided Exercise Sessions		
	n	%	n of ES	n	%	n of ES
Percentage of Completed Exercise Sessions (ES) with Reference to the Target						
0–24%	9	20	0–12	13	30	0–6
25–49%	11	25	13–25	13	30	7–12
50–74%	7	16	26–38	13	30	13–19
75–100%	17	39	39–52	5	11	20–26
	44	100		44	100	

Compliance 6–12 Months, Training Group

	Self-kept Exercise Diary			Guided Exercise Sessions		
	n	%	n of ES	n	%	n of ES
Percentage of Completed Exercise Sessions (ES) with Reference to the Target						
0–24%	20	50	0–12	24	60	0–6
25–49%	5	12	13–25	5	13	7–12
50–74%	8	20	26–38	6	14	13–19
75–100%	7	18	39–52	5	13	20–26
	40	100		40	100	

cises in a correct way and understood the principle of NZ, and felt that the intensity of exercises was suitable. The main reason for missing ES was recurrent but not training related LBP (51%). The experiences at 12 months were similar.

Effectiveness

The effects of the intervention on LPB and disability at 6 and 12 months are presented in Table 5. The intensity of LBP decreased significantly more (39%) in the TG when compared with the CG at 12 months as assessed by VAS during the past 7 days ($P = 0.032$) and 2 months ($P = 0.052$). The differences at 6 months were not significant, but there was a trend for VAS during the past 7 days to decrease more (30%) in TG than CG. For more closely looking at the changes in LBP, the medians at baseline and at 12 months are presented in the subgroups with low (0–19 mm) and high (≥20 mm) baseline levels of VAS scores in Figure 2. There were small positive changes in ODI and PDI in both groups, but the differences between the groups were not statistically significant at either measurement.

The proportion of subjects with negative expectations about their future work ability decreased statistically significantly more in the TG than in CG (Figure 3). The proportion of subjects with low neuromuscular fitness decreased somewhat in most tests in both groups. The only difference in changes between TG and CG was in one-leg standing balance test with borderline statistical significance ($P = 0.052$) at the 6-month follow-up. Proportion of subjects with poor balance (*i.e.*, not able to stand on one leg for 60 seconds) in TG decreased from 37% to 9% and in CG from 23% to 15%. The odds ratio for low fitness after 6 month training was 0.19 (with 95% CI from 0.04 to 1.01) in TG with reference to CG. A corresponding but weaker association was found at the 12-month follow-up (odds ratio, 0.20; 95% CI, 0.03–1.18, $P = 0.08$). None of the men in TG who completed at least

Table 5. Effectiveness of the Intervention on Low Back Pain and Disability at 6 and 12 Months

Outcome Measure	n	Geometric Means		Geometric Mean Ratios* Adjusted for Baseline	
VAS, past 7 d		Baseline	At 6 mos	At 6 mos (95% confidence interval)	*P*†
Training group	44	10.8	7.1	0.70 (0.43 to 1.13)	*P* = 0.14
Control group	47	11.2	10.3		
		Baseline	At 12 mos	At 12 mos (95% confidence interval)	
Training group	38	9.9	5.5	0.61 (0.38 to 0.97)	*P* = 0.032
Control group	42	11.8	10.2		
VAS, past 2 mos		Baseline	At 6 mos	At 6 mos (95% confidence interval)	
Training group	44	16.2	12.6	0.97 (0.59 to 1.59)	*P* = 0.91
Control group	47	17.2	13.5		
		Baseline	At 12 mos	At 12 mos (95% confidence interval)	
Training group	38	15.3	8.6	0.61 (0.47 to 1.00)	*P* = 0.052
Control group	42	15.8	14.3		
ODI		Baseline	At 6 mos	At 6 mos (95% confidence interval)	
Training group	44	5.9	4.5	0.87 (0.70 to 1.08)	*P* = 0.20
Control group	48	5.9	5.2		
		Baseline	At 12 mos	At 12 mos (95% confidence interval)	
Training group	39	5.6	4.8	0.98 (0.79 to 1.23)	*P* = 0.88
Control group	45	5.8	5.0		
PDI		Baseline	At 6 mos	At 6 mos (95% confidence interval)	
Training group	44	5.9	4.5	0.80 (0.58 to 1.12)	*P* = 0.20
Control group	48	5.9	5.2		
		Baseline	At 12 mos	At 12 mos (95% confidence interval)	
Training group	39	5.6	4.8	0.86 (0.57 to 1.29)	*P* = 0.46
Control group	45	5.8	5.0		

*Training group compared with control group.
†Analysis of covariance.
VAS indicated Visual Analog Scale; ODI, Oswestry Disability Index, PDI, Pain and Disability Index.

75% of the target amount of training (n = 17) had poor balance at the 6-month follow-up.

Discussion

Effects

The main purpose of the present study was to investigate the effects of a new NTCI that emphasized the principle of lumbar NZ in all activities of daily life as secondary prevention for LBP and disability. It proved to be safe and feasible as well as effective in terms of decreasing the intensity of LBP and enhancing positive changes in self-evaluated work ability. There were no effects on disability indexes and a small positive effect on static balance.

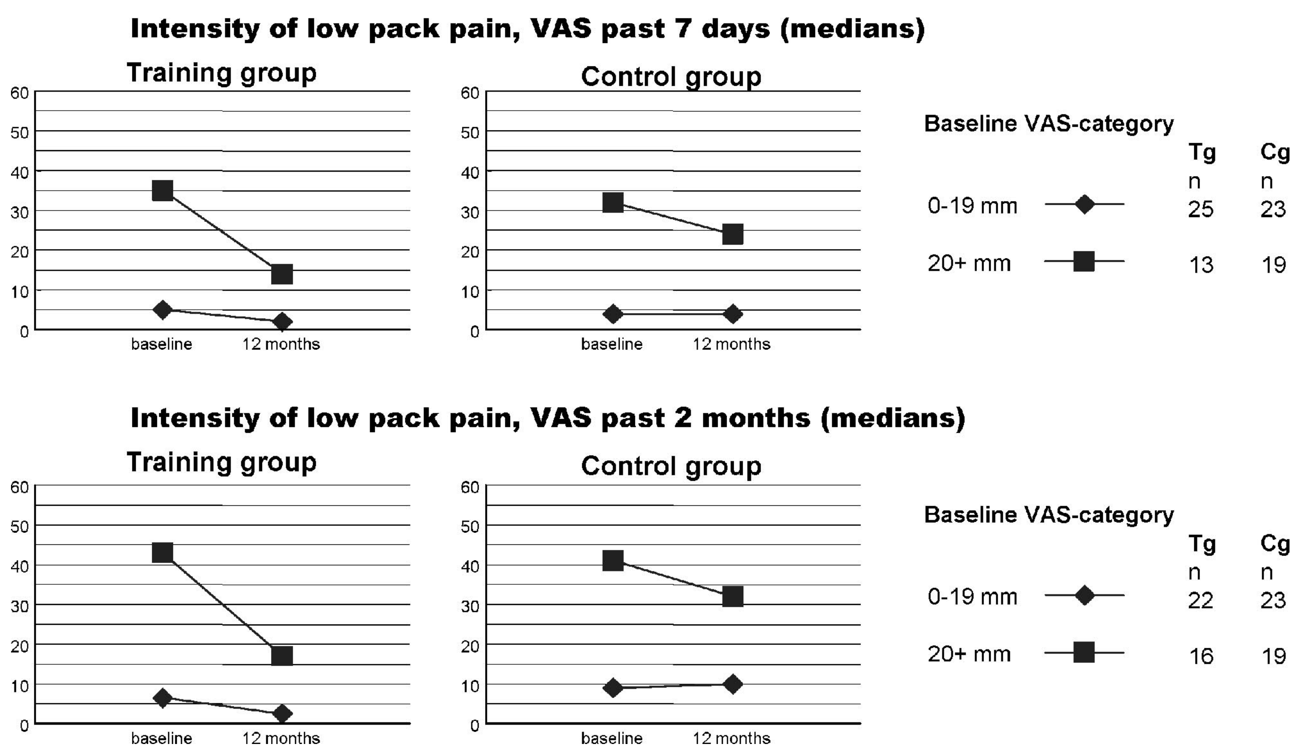

Figure 2. The changes in pain intensity scores as assessed by Visual Analog Scales (VAS) in subgroups of low and high baseline category among the training and control group.

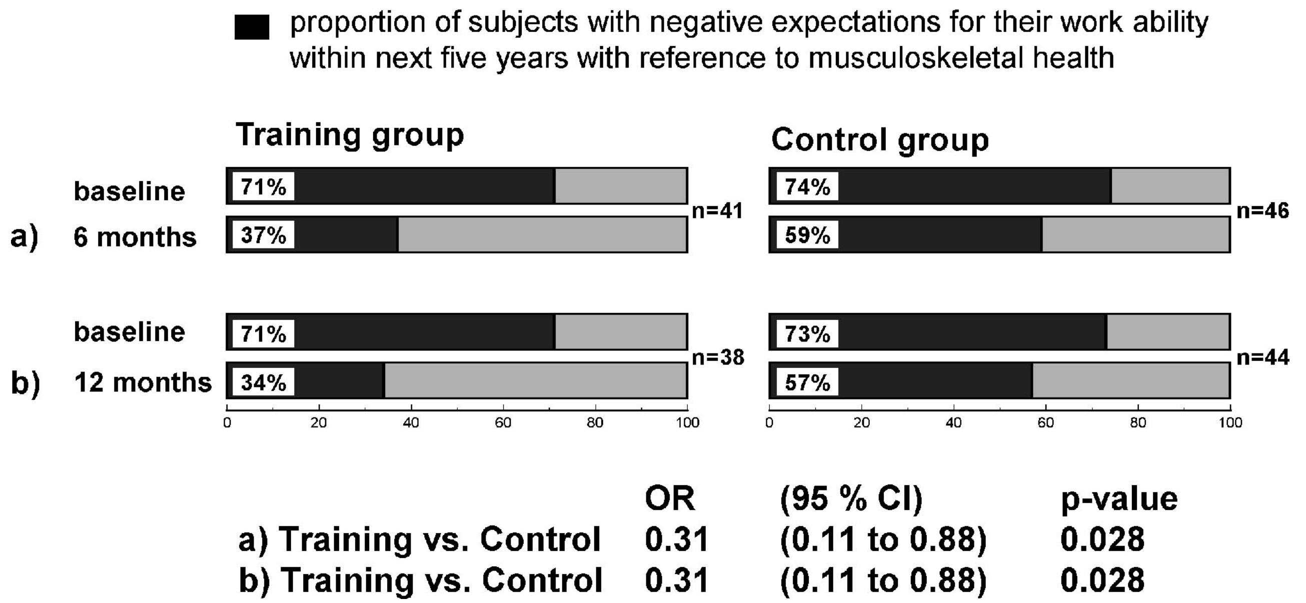

Figure 3. The changes in proportions of subjects with negative expectations for their work ability within the next 5 years with reference to musculoskeletal health, and the differences in changes between the training and control group (odds ratios with 95% confidence intervals [CI]).

Effective treatment of pain is the key issue in the prevention of chronic LBP and disability.[3,25,42] The intervention described in the present study was successful in reducing the intensity of LBP in the TG despite the low baseline levels of VAS scores. Based on the further analysis among subjects with low or higher baseline VAS scores, we considered the alleviation of LBP clinically important within the framework of secondary prophylaxis for recurrence of LBP. Our findings agree with a former early rehabilitation study among nurses.[31]

Likely because of inadequate training stimulus, there were no significant improvements in flexibility or trunk muscular endurance, and only a borderline improvement in static balance in TG compared with CG. We propose that the mechanism for decreased intensity of LBP was improved control of the lumbar NZ, which decreased

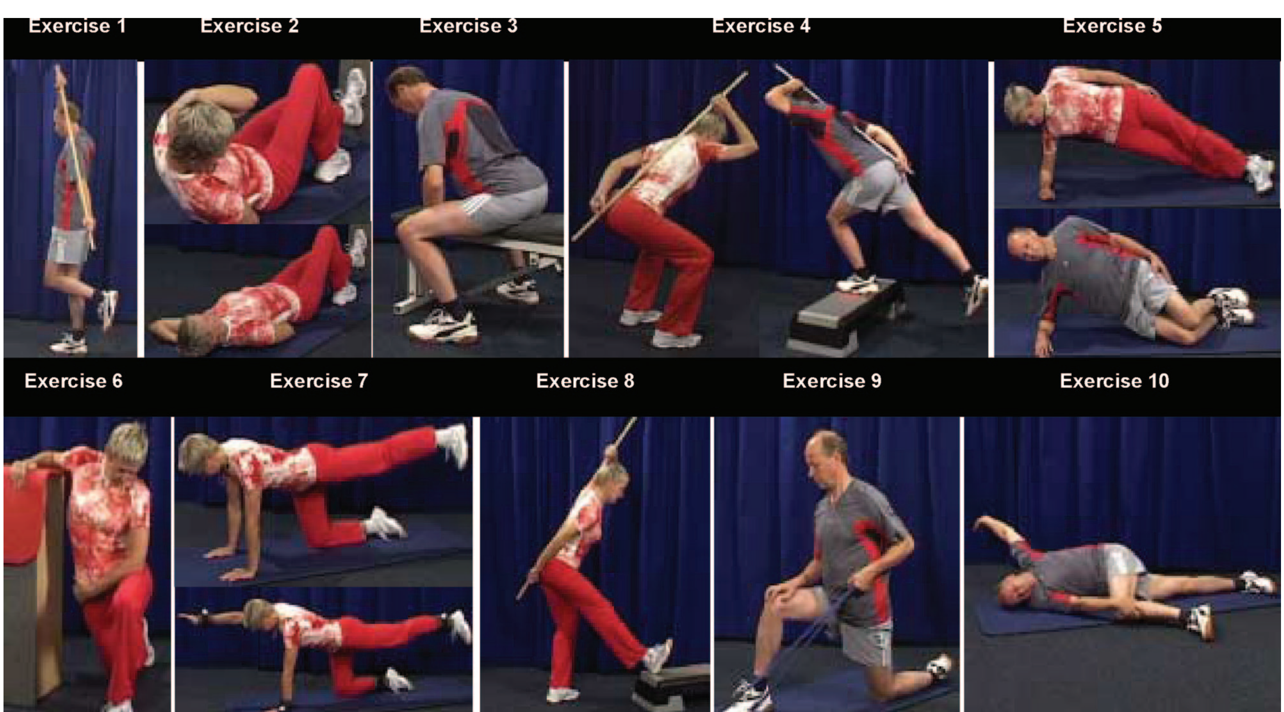

Figure 4. Illustrations of the 10 exercises included in the neuromuscular training program (the numbers of the exercises correspond with the exercise numbers given in Table 1).

harmful loading to the structures of lower back. In other words, the subjects in TG learned to control the lumbar NZ in the exercises and were able to apply these skills in their daily activities. This suggestion is supported by the experiences of majority of men in TG at 6 and 12 months, when they expressed having had enough guidance and counseling to perform the exercises in a correct way and understood the principle of lumbar NZ.

The baseline scores for both ODI and PDI among the study subjects were so low toward no disability (Table 3) that improvements in them were considered rather unrealistic. The low scores indicate that the selected subjects were not chronic LBP patient,[31] but rather a group of men with recurrent LBP problems who were still well able to work. All these facts agree with the inclusion criteria for the study. Outcome measures covering a wider variety of tasks of daily life, such as the Disability Rating Index by Salen *et al*,[43] may be a more useful tool in assessing the changes in functional ability among patients with recurrent but not chronic LBP.

At baseline, the proportion of subjects with negative expectations for self-evaluated work ability within the next 5 years in terms of musculoskeletal health was high in both groups. After the 12-month intervention, the self-rated workability improved in both groups, however, the proportion of improved men in TG was about twice of that in CG. We suggest that positive experiences of training and counseling intervention may have enhanced these positive chances in the TG. The present intervention had a clear premade plan on how to change the attitudes and behavior of the subjects to help them better manage their current LPB and prevent future episodes. The process included 1) experimental learning of controlling the lumbar NZ thru the exercise program, 2) learning to apply the new skills in real life situations with the help of individual counseling and motivational support, and 3) becoming more aware of the life situations where preserving the neutral lumbar curvature was problematic, which is necessary for conscious change of behavior.[44]

Strengths and Limitations

The strength of the present study was the randomized controlled trial design as well as the careful introduction of the targets of NTCI and detailed description of the objective, order, and dosage of each exercise.[45] However, since the blinded design is not possible in this type of clinical study, the cointervention effect cannot be ruled out. In other words, the subjects who were exercising may have experienced less pain and evaluated their work ability better because they knew they were in the intervention group.

The lack of measurement tool capable of assessing wide variety of daily activities among subjects with recurrent, but not chronic, LBP limited the evaluation of effectiveness of the NTCI on functional disability in the present study.

The long duration of the intervention (12 months) and limited training compliance during the last 6 months may be considered as limitations for future applications. We would like to point out that stable changes in behavior typically began to formulate only after 6 months of "experimental phase" and become more regular after 12 months.[46] For future applications, we recommend that the first 6 months of the proposed intervention is conducted as presented, followed by a 6-month guided training and counseling 2 or 3 times a month.

Former physical training interventions aimed at secondary prophylaxes of LBP have most typically investigated the effects of training on muscular strength, muscular endurance, and flexibility.[47] An additional strength of the present study was that the rationale of the NTCI was based on the latest theories and study findings on the prevention of recurrent LBP. The findings of two former early rehabilitation studies of LPB[23,24] and one study on chronic patients[22] that have included the control of lumbar NZ as one goal of their intervention, have been promising. Both Lönn *et al*[23] and Soukup *et al*[24] gave 20 group sessions, including exercise and ergonomic counseling during 13 weeks, and reported significant reduction in the incidence of LBP recurrences after 12 months. Based on these two former studies and the findings of the present study, we conclude that controlling lumbar NZ is a specific form of self-care with potential for prevention of recurrence of nonspecific LBP and disability among middle-aged working men.

■ Key Points

- There is a need for early interventions aimed at prevention of recurrence of low back pain and disability.
- A randomized controlled trial that evaluated the effectiveness of a training intervention with emphasis on the control of lumbar neutral zone and behavior modeling was conducted.
- The results show a reduction in the intensity of low back pain and improvement in self-evaluated future work ability with reference to musculoskeletal health.
- Early interventions including neuromuscular training and behavior modeling on the control of lumbar neutral zone have potential for prevention of recurrent nonspecific low back pain and disability.

Acknowledgment

The authors thank senior researcher Ritva Nupponen, PhD, for her expert help in the planning of the counseling process of the intervention.

References

1. Coste J, Delecoueuillerie G, Cohen de Lara A, et al. Clinical course and prognostic factors in acute low back pain: an inception cohort study in primary care practice. *BMJ* 1994;308:577–80.

2. Von Korff M, Deyo RA, Cherkin D, et al. Back pain in primary care: outcomes at one year. *Spine* 1993;18:855–62.
3. Linton SJ, Andersson T. Can chronic disability be prevented? A randomized trial of a cognitive-behaviour intervention and two forms of information for patients with spinal pain. *Spine* 2000;25:2825–31.
4. Brumagne S, Cordo P, Lysens R, et al. The role of paraspinal muscle spindles in lumbosacral position sense in individuals with and without low back pain. *Spine* 2000;25:989–94.
5. Hodges PW. Changes in motor planning of feedforward postural responses of the trunk muscles in low back pain. *Exp Brain Res* 2001;141:261–6.
6. Radebold A, Cholewicki J, Panjabi MM, et al. Muscle response pattern to sudden trunk loading in healthy individuals and in patients with chronic low back pain. *Spine* 2000;25:947–54.
7. Radebold A, Cholewicki J, Polzhofer GK, et al. Impaired postural control of the lumbar spine is associated with delayed muscle response times in patients with chronic idiopathic low back pain. *Spine* 2001;26:724–30.
8. Hodges PW, Moseley GL. Pain and motor control of the lumbopelvic region: effect and possible mechanisms. *J Electromyogr Kinesiol* 2003;13:361–70.
9. McGill SM. The biomechanics of low back injury: implications on current practice in industry and the clinic. *J Biomech* 1997;30:465–75.
10. McGill SM. Low back disorders. In: *Evidence-Based Prevention and Rehabilitation*. Champaign, IL: Human Kinetics, 2002.
11. O'Sullivan PB. Motor control and pain disorders of the lumbo-pelvic region. In: *5th Interdisciplinary World Congress on Low Back and Pelvic Pain*, Melbourne, Australia, 2004:129–36.
12. McGill SM, Kippers V. Transfer of loads between lumbar tissues during the flexion-relaxation phenomenon. *Spine* 1994;19:2190–6.
13. Dolan P, Adams MD. Effects of lumbar and hip mobility on the bending stresses acting on the lumbar spine. *Clin Biomech* 1993;8:185–92.
14. Cholewicki J, Panjabi MM, Khachatryan A. Stabilizing function of trunk flexor-extensor muscles around a neutral spine posture. *Spine* 1997;22: 2207–12.
15. Juker D, McGill S, Kropf P, et al. Quantitative intramuscular myoelectric activity of lumbar portions of psoas and the abdominal wall during wide variety of tasks. *Med Sci Sports Exerc* 1998;30:301–10.
16. Kavcic N, Grenier S, McGill S. Determining the stabilizing role of individual torso muscles during rehabilitation exercises. *Spine* 2004;29:1254–65.
17. McGill SM, Hughson RL, Parks K. Changes in lumbar lordosis modify the role of the extensor muscles. *Clin Biomech* 2000;15:777–80.
18. Richardson CA, Jull GA, Hodges PW, et al. *Therapeutic Exercise for Spinal Segmental Stabilization in Low Back Pain*: *Scientific Basis and Clinical Approach*. Edinburgh: Churchill Livingstone, 1999.
19. Hodges PW. Core stability exercise in chronic low back pain. *Orthop Clin North Am* 2003;34:245–54.
20. McGill SM. *Ultimate Back Fitness and Performance*. Ontario, Canada: Wabuno, 2004.
21. Akuthota V, Nadler SF. Core strengthening. *Arch Phys Med Rehabil* 2004; 85(suppl):86–92.
22. Snook SH, Webster BS, McGorry RW, et al. The reduction of chronic nonspecific low back pain through the control of early morning lumbar flexion. *Spine* 1998;23:2601–7.
23. Lönn JH, Glomsrod B, Soukup MG, et al. Active back school: prophylactic management for low back pain: a randomized, controlled, 1-year follow-up study. *Spine* 1999;24:865–71.
24. Soukup MG, Glomsröd B, Lönn JH, et al. The effect of a Mensendieck exercise program as secondary prophylaxis for recurrent low back pain: a randomized, controlled trial with 12-month follow-up. *Spine* 1999;24: 1585–92.
25. Hides JA, Jull GA, Richardson CA. Long-term effects of specific stabilizing exercises for first-episode low back pain. *Spine* 2001;26:E243–8.
26. Von Korff M, Moore JE, Lorig K, et al. A randomized trial of a lay-led self-management group intervention for back pain patients in primary care. *Spine* 1998;23:2608–15.
27. Karjalainen K, Malmivaara A, Pohjolainen T et al. Mini-intervention for subacute low back pain: a randomized controlled trial. *Spine* 2003;28: 535–41.
28. Lindström I, Öhlund C, Eek C, et al. The effect of graded activity on patients with subacute low back pain: a randomized prospective clinical study with on operant-conditioning behavioral approach. *Phys Ther* 1992;72:279–93.
29. Kuorinka I, Jonsson B, Kilbom A, et al. Standardized Nordic questionnaires for the analysis of musculoskeletal symptoms. *Appl Ergon* 1997;18:233–7.
30. Huskinsson EC. Measurement of pain. *Lancet* 1974;2:1127–31.
31. Cooper JE, Tate RB, Yassi A, et al. Effect of an early intervention program on the relationship between subjective pain and disability measures in nurses with low back injury. *Spine* 1996;20:2329–36.
32. Fairbank JCT, Couper J, Davies JB, et al. The Oswestry low back pain and disability questionnaire. *Physiotherapy* 1980;66:271–3.
33. Frost H, Lamb SE, Klaber Moffett JA, et al. A fitness programme for patients with chronic low back pain, 2-year follow-up of a randomised controlled trial. *Pain* 1998;75:273–9.
34. Pollard CA. Preliminary validity study of the Pain Disability Index. *Percept Mot Skills* 1984;59:974.
35. Chinball JT, Raymond MS, Tait C. The pain disability index: factor structure and normative data. *Arch Phys Med Rehabil* 1994;75:1082–6.
36. Kankaanpää M, Taimela S, Airaksinen O, et al. The efficacy of active rehabilitation in chronic low back pain. *Spine* 1999;24:1034–42.
37. Suni JH, Miilunpalo SI, Asikainen T-M, et al. Safety and feasibility of a health-related fitness test battery for adults. *Phys Ther* 1998;78:134–48.
38. Suni JH, Oja P, Laukkanen RT, et al. Development of a health-related fitness test battery for adults: aspects of reliability. *Arch Phys Med Rehabil* 1996; 77:399–405.
39. Rinne MB, Pasanen ME, Miilunpalo SI, et al. Test-retest reproducibility and inter-rater reliability of a motor skill test battery for adults. *Int J Sports Med* 2001;22:192–200.
40. UKK Institute, htpp://*www.ukkinstituutti.fi*/tietokeskus/materiaalitilaukset [in Finnish].
41. Suni JH, Oja P, Miilunpalo SI, et al. Health-related fitness test battery for middle-aged adults: associations with physical activity patterns. *Int J Sports Med* 1999;20:183–91.
42. Luoto S, Aalto H, Taimela S, et al. One-footed and externally disturbed two-footed postural control in patients with chronic low back pain and healthy control subjects. *Spine* 1998;23:2081–90.
43. Salen BA, Spangefort EV, Nygren ÅL, et al. The disability rating index: an instrument for the assessment of disability in clinical settings. *J Clin Epidemiol* 1994;47:1423–34.
44. Magill RA. *Motor Learning and Control*: *Concepts and Applications*, 7th ed. New York: McGraw-Hill, 2004.
45. Staal JB, Hlobil H, van Tulder MW, et al. Return-to-work interventions for low back pain. *Sports Med* 2002;32:251–67.
46. Laitakari J, Miilunpalo S. How can physical activity be changed? Basic concepts and general principles in the promotion of health-related physical activity. *Patient Educ Couns* 1998;33(suppl):47–59.
47. Linton SJ, van Tulder MW. Preventive interventions for back and neck pain problems: what is the evidence? *Spine* 2001;26:778–87.