Pilates-Based Therapeutic Exercise: Effect on Subjects With Nonspecific Chronic Low Back Pain and Functional Disability: A Randomized Controlled Trial

Rochenda Rydeard, PT, MSc[1]
Andrew Leger, PT, PhD[2]
Drew Smith, PhD[3]

Study Design: A randomized controlled trial, pretest-posttest design, with a 3-, 6-, and 12-month follow-up.

Objectives: To investigate the efficacy of a therapeutic exercise approach in a population with chronic low back pain (LBP).

Background: Therapeutic approaches developed from the Pilates method are becoming increasingly popular; however, there have been no reports on their efficacy.

Methods and Measures: Thirty-nine physically active subjects between 20 and 55 years old with chronic LBP were randomly assigned to 1 of 2 groups. The specific-exercise-training group participated in a 4-week program consisting of training on specialized (Pilates) exercise equipment, while the control group received the usual care, defined as consultation with a physician and other specialists and healthcare professionals, as necessary. Treatment sessions were designed to train the activation of specific muscles thought to stabilize the lumbar-pelvic region. Functional disability outcomes were measured with The Roland Morris Disability Questionnaire (RMQ/RMDQ-HK) and average pain intensity using a 101-point numerical rating scale.

Results: There was a significantly lower level of functional disability (P = .023) and average pain intensity (P = .002) in the specific-exercise-training group than in the control group following the treatment intervention period. The posttest adjusted mean in functional disability level in the specific-exercise-training group was 2.0 (95% CI, 1.3 to 2.7) RMQ/RMDQ-HK points compared to a posttest adjusted mean in the control group of 3.2 (95% CI, 2.5 to 4.0) RMQ/RMDQ-HK points. The posttest adjusted mean in pain intensity in the specific-exercise-training group was 18.3 (95% CI, 11.8 to 24.8), as compared to 33.9 (95% CI, 26.9 to 41.0) in the control group. Improved disability scores in the specific-exercise-training group were maintained for up to 12 months following treatment intervention.

Conclusions: The individuals in the specific-exercise-training group reported a significant decrease in LBP and disability, which was maintained over a 12-month follow-up period. Treatment with a modified Pilates-based approach was more efficacious than usual care in a population with chronic, unresolved LBP. *J Orthop Sports Phys Ther 2006;36(7):472-484.* doi:10.2519/jospt.2006.2144

Key Words: *exercise rehabilitation, lumbar spine muscle recruitment, stabilization exercises*

[1] *Graduate student (at time of study), School of Rehabilitation Therapy, Queen's University, Kingston, Ontario, Canada.*
[2] *Educational Developer, Centre for Teaching and Learning, Queen's University, Canada; Assistant Professor (at time of study), School of Rehabilitation Therapy, Queen's University, Kingston, Ontario, Canada.*
[3] *Senior Lecturer, Department of Sport and Exercise Science, The University of Auckland, Auckland, New Zealand; Assistant Professor (at time of study), Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hung Hom, Hong Kong SAR, China.*
The protocol for this study was approved by The Faculty of Health Science Research Ethics Board, Queens University, Canada and Hong Kong Polytechnic University Human Subjects Ethics Subcommittee, Hong Kong Special Administrative Region.
Address corresondence to A. B. Leger, Centre for Teaching and Learning, Queen's University, Kingston, Ontario K7L 3N6, Canada. E-mail: AL7@post.queensu.ca

Low back pain (LBP) represents the most common cause of disability in persons under 45 years of age.[1] Spinal disorders represent at least 40% of the compensated disorders treated by physiotherapists, and 70% of these spinal disorders involve the lumbar spine.[39]

The effectiveness of therapeutic exercise in the treatment of chronic LBP is currently under review.[22,28,39,43,44] General conditioning programs to train strength and endurance of the spine musculature have been shown to reduce pain intensity and disability[28] and to be useful in the treatment of nonspecific chronic LBP[22,44] and "activity-related spinal disorders."[39] Much of the literature examining chronic LBP and exercise interventions study a population whose pain and disability manifest in "deconditioning syndrome," as described by Mayer.[22] It follows that exercise-training programs directed generally at muscle strength, endurance, and reconditioning are appropriate. However, physical deconditioning may not be the limiting factor to recovery for many patients seeking treatment for chronic low back disorders; it is now accepted that muscle dysfunction in chronic LBP may not simply be a problem of muscle strength or endurance. Instead, the problem may be one of altered neuromuscular control mechanisms affecting muscular stability of the trunk and movement efficiency.[5,15,17,29] Bergmark[3] classifies spinal stability as being comprised of 2 (muscular) mechanisms: local mechanisms, whereby deep, local muscles act to control movement at the intervertebral segment, and global mechanisms, whereby muscles control movement of the spine generally and at multiple segments. Effective control of both mechanisms is necessary for efficient stabilization of the spine and alterations in neuromuscular control and the loss of normal patterns of spinal motion will cause pain.[26] Further, Edgerton et al[5] suggest that pain and pathology result in changes in neural input to motor neuron pools affecting muscle activation. A general reconditioning approach, through its lack of specificity, may reinforce abnormal muscle recruitment and perpetuate compensatory strategies that may have developed as a result of neuromuscular adaptation over time.

Consequently, specifically designed therapeutic exercise approaches that enhance spinal stability and modulate neuromuscular control in the presence of chronic LBP have been embraced by physiotherapists. Techniques evaluated in the literature to date address muscle activation directed at the intervertebral segment via the cocontraction of the deep abdominals and the paraspinals, enhancing stabilization at the lumbar spine segments.[25] Recent evidence supports the effectiveness of such a specific-exercise approach in a chronic LBP population with a diagnosis of spondylolysis or spondylolisthesis.[25,44] O'Sullivan and colleagues[25] found a significant reduction in pain intensity (P = .0006) and functional disability levels (P = .0001) in a group who received specific exercise with maintenance of effect over a 30-month follow-up. No significant changes were seen in a control group receiving usual care.

The Pilates Method[37] is an exercise method popular for decades in dance training and the dance medicine community. The Pilates Method is a unique approach to training in mind-body awareness and control of movement and posture. Specialized apparatus provides an opportunity to train a variety of movement patterns and postures. The neuromuscular demands of traditional Pilates methods can be quite high and therefore a modification of this method is necessary for application to physiotherapeutic interventions. The technique used in this study was adapted but consistent with traditional Pilates techniques, focusing on postural symmetry and controlled movement. Particular emphasis, however, was placed on specific muscle activation strategies thought to stabilize the lumbar-pelvic region.

A modified Pilates approach to improve posture and control movement can thus be supported within a theoretical context of neuromuscular control and builds upon the concept of stability about a local spinal segment. Global stability mechanisms to control the lumbar-pelvic region are then incorporated into this background of segmental lumbar control. This may be achieved by incorporating specific activation of the gluteal muscles to stabilize the lumbar-pelvic region while performing hip extension.[34,35] Stability of the trunk is thereby accomplished by using an overlapping of stabilization strategies. Further, the use of Pilates apparatus to train stabilization strategies during movement may enhance the effect of a relatively more static mat exercise. This may be important for retention of treatment effects and transfer to everyday movement and functional activities.

The function of the hip extensors and the gluteus maximus is thought to be central to stability and control in the lumbar-pelvic region.[14,18] The gluteus maximus muscle may play an important role in lumbar-pelvic mechanics and load transfer from the lumbar spine to the pelvis and lower extremities.[46] Altered recruitment of the lumbar-pelvic musculature and dysfunction of the gluteus maximus muscle is reported in LBP conditions.[4,24,47] Janda[14,15] describes a characteristic "pseudoparesis" of the gluteus maximus in LBP, characterized by hypotonia and a delay in activation. A concomitant imbalance in the functional length or recruitment of the hamstrings and/or superficial lumbar erector spinae relative to the gluteus maximus has been associated with LBP.[2,13-15,24,36] The resultant pull of muscle forces may impact adversely on neuromuscular control of hip extension and the ability of the trunk to stabilize effectively against the demands of loading during activities such as walking.

Evidence supporting the effect on pain and disability from specific exercise approaches applied to nonspecific chronic LBP has not been confirmed. Similarly, no studies to date have examined the effects of a specific exercise training approach that emphasizes lumbar-pelvic stability and the function of the gluteus maximus. As well, no clinical research activities have been reported to date that elucidate the efficacy of an exercise intervention based on the Pilates Method in the treatment of chronic LBP.

Therefore, the objectives of this study were to investigate the efficacy of a specific-exercise intervention based on the Pilates Method and emphasizing specific-activation strategies of the gluteus maximus

RESEARCH REPORT

and the effect on LBP intensity and functional disability in an identified population with nonspecific chronic LBP.

METHODS

Subjects

Fifty-five subjects were recruited over a 4-month period through notices posted to private and public physicians' and physiotherapists' offices, notices posted to local sports clubs and Universities, and by advertisement in an English-language newspaper (Figure 1). The subjects were recruited from a population of physically active adults between 20 and 55 years of age, living in Hong Kong, with longstanding, persistent LBP (with or without leg pain) of greater than 6 weeks duration or recurring LBP (with at least 2 painful incidences per year) of sufficient intensity to restrict functional activity in some manner. "Physically active" was defined as participation in a minimum of three 30-minute sessions per week of activity requiring a moderate effort in keeping with established guidelines for physical fitness.[6,42] This criterion ensured that findings cannot simply be attributed to disuse secondary to deconditioning and low activity levels. Similarly, this criterion may have helped to eliminate those LBP conditions that might have responded to general physical conditioning exercise without requiring more specific neuromuscular training. Subsequent clinical screening was performed by an independent physiotherapist evaluator to test for evidence of neuromuscular dysfunction and fulfillment of the following criteria: (*a*) strength recording of grade 4 or less out of 5 on manual muscle testing of the gluteus maximus[14,18]; (*b*) altered recruitment of the gluteus maximus muscle as determined clinically by visual and manual inspection during a prone leg extension test.[13,36,38]

Prospective subjects were excluded from the study if they were pregnant, had a past history of spinal surgery or spinal fracture, were diagnosed with inflammatory joint disease, systemic metabolic disorder, rheumatic disease, or chronic pain syndrome, showed evidence of overt neurological compromise or acute inflammatory process, or had difficulty understanding written or spoken English. Thirty-nine subjects met the selection criteria for inclusion in the study and 16 subjects were excluded. Testing was performed at the Hong Kong Polytechnic University. The clinical intervention was conducted at a private physiotherapy clinic in Hong Kong, which specialized in Pilates-based interventions. All subjects signed informed consent forms upon entry to the trial and the rights of the subjects were protected. The Faculty of Health Science Research Ethics Board, Queens University, Kingston, Ontario and the Hong Kong Polytechnic University Human Subjects Ethics Subcommittee, Hong Kong Special Administrative Region, granted ethics approval for the study. Subject characteristics are reported in Table 1.

Study Design

The study consisted of 2 parts, a pretest-posttest control group design in part 1 (the primary study) and in part 2 (a follow-up on the exercise intervention group over a 1-year period). Simple randomization was performed at entry to the trial after eligibility was determined. Randomization was administered by independent office staff. Subjects randomly pulled a card from a box of concealed premarked cards to obtain assignment to either the specific-exercise-training group (SETG) or control group (CG) without specific exercise training (Figure 1). The subjects had no preconceived expectations for treatment because at the time of the study the Pilates method was not commonly known. The subjects were advised that the study was designed to evaluate the effectiveness of this specific-exercise intervention in the treatment of LBP.

Intervention

Those in the CG group received no specific exercise training and continued with usual care, defined as consultation with a physician and other specialists and healthcare professionals as necessary. They were not restricted from seeking any other treatment if they so wished. Subjects were instructed to continue to do what they were previously doing, including regular physical activity. For ethical reasons the CG had the option to receive, free of charge, the specific-exercise-training program 4 weeks later, after collection of posttreatment intervention outcome data from the main study. During the main study period, although subjects were aware they could receive the exercise intervention, they were not familiar with the technique or aware of any details of what the treatment entailed.

The SETG received a treatment protocol consisting of training on specialized (Pilates) exercise apparatus in the clinic for three 1-hour sessions per week, and training in a 15-minute home program performed 6 days per week for 4 weeks. Treatment was provided at no charge to the subjects. The apparatus used in the clinic consisted of a floor mat and a Pilates Reformer with standing platform and jump-board attachments (Balanced Body, Sacramento, CA). The Pilates Reformer is made of a sliding horizontal platform within a box-like frame, upon which the subject sits, stands, kneels, or reclines. Varying resistance to movement is provided via light springs attached to the moving platform and through a simple pulley system. The subject moves against the low external resistance offered by the springs.

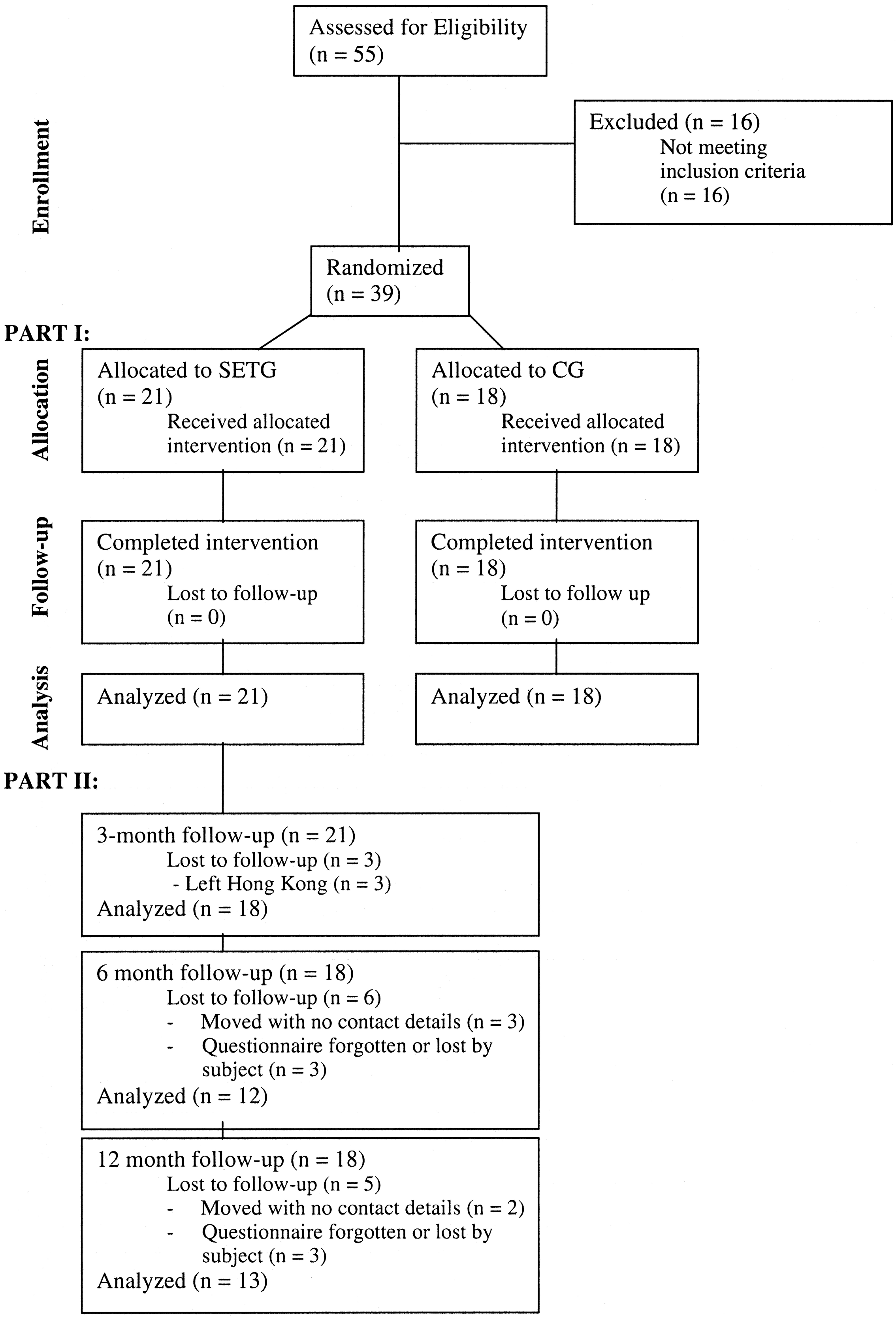

Figure 1. Subject flow during the study.

TABLE 1. Subject characteristics and demographic data for the specific exercise-training group (SETG) and the control group (CG).

Subject Characteristics	CG	SETG	*P* Value
Gender			*P* = .77*
Male	8	6	
Female	13	12	
Age (y)	34 (8)	37 (9)	*P* = .34†
Height (cm)	171(10)	169 (8)	*P* = .65†
Mass (kg)	69 (15)	68 (14)	*P* = .92†
Duration of symptoms (y)	Median, 9 (range, 1-20)	Median, 5.5 (range, 0.5-27.0)	*P* = .25‡
Nature of condition			*P* = .58*
Chronic	16	15	
Recurrent	5	3	
Area of symptoms			*P* = .27*
Low back pain (LBP)	11	9	
LBP and leg pain above knee	3	6	
LBP and leg pain below knee	7	3	
Previous physiotherapy treatment	19	16	*P* = .87*
Included exercise therapy	15	14	*P* = .65*
Functional disability (mean ± SD)	4.2 ± 3.6	3.1 ± 2.5	*P* = .14†
Pain intensity score (mean ± SD)	30.4 ± 17.6	23.0 ± 17.7	*P* = .56†

* Chi-Square test.
† Unpaired *t* test.
‡ Mann-Whitney *U* test.

The clinic treatment protocol was provided in an individualized manner by 1 of 2 experienced physiotherapists trained in the treatment protocol and blinded to the results of testing. The standardized, progressive treatment protocol addressed targeted muscle activation strategies throughout a variety of movement patterns involving hip extension. The subject was required to consciously recruit specific muscles—the deep anterolateral abdominals (with coactivation of the pelvic floor and lumbar multifidus), followed by activation of the gluteus maximus muscles. Static postures were initially trained (Figure 2), followed by training a variety of movement patterns to stress the lumbar-pelvic region and involving hip extension (Figure 3). The training was progressed on the Pilates Reformer (Figure 4) over the 4-week period as tolerated. Initially movements were practiced using weight-bearing patterns in supine, with the lumbar spine in the neutral position. Gradually more upright postures and controlled movement of the lumbar-pelvic region out of neutral posture were incorporated. Prescribed movements were performed slowly, smoothly, and without pain. Individualized facilitation strategies were provided by the physiotherapist to correct technique, control speed, assist appropriate muscle activation, or modify the exercise or the progression to suit the subjects' needs. Facilitation strategies included mental and visual imagery, manual or verbal cueing, and demonstration.

The home treatment protocol consisted of 2 parts: (1) floor exercises to specifically activate the deep anterolateral abdominals and local stability synergists[31] and the gluteus maximus muscle by moving the leg in a manner similar to that utilized on the apparatus (Figures 2 and 3) and (2) skill drills in which difficult tasks were broken down into movement components and practiced in isolation incorporating correct abdominal and gluteal control. Compliance with the home exercise program was encouraged and was self-monitored on a log sheet. The treating physiotherapist kept clinical notes documenting details of the treatment program and the subject's progress.

Outcome Measure Testing

Data collection monitored both pain intensity and functional status and included 2 self-report questionnaires administered by the research assistant, an independent physiotherapist investigator blinded to group assignment. In part 1 all subjects were tested on baseline measures at entry to the study (pretesting). Retesting of both groups was done at the end of the 4-week treatment intervention period (posttesting). In part 2, disability measures for retention of treatment effect were collected from the SETG using a questionnaire mailed to the subjects over a 12-month follow-up period.

Pain Intensity Outcome The NRS-101, a 101-point numerical rating scale, was used to measure subjective pain intensity.[16] The subject rated his or her perceived pain level between 0 and 100, with 0 representing no pain and 100 representing pain as bad as it could be. The test protocol asked subjects to verbally state the number that best described the average amount of pain they had experienced in the past week. The number noted by the subject was recorded on the subject's record card and used for data analysis.

Figure 2. The subject was required to consciously recruit specific muscles: the deep anterolateral abdominals (with coactivation of the pelvic floor and lumbar multifidus), followed by activation of the gluteus muscle to control a static posture.

Functional Disability Outcome Functional disability was evaluated with the RMQ[32,33] and the RMDQ-HK.[11] This tool is a self-administered questionnaire listing activities that can be compromised by LBP. The RMQ (English version)/RMDQ-HK (Chinese version validated in a Hong Kong Chinese population) is a self-administered questionnaire consisting of 24 items to measure disability secondary to LBP. The scores range from 0 to 24, with 0 representing no disability and a score of 24 indicating severe disability.

Statistical Analysis

Statistical analysis was performed using SPSS software. Results were considered statistically significant if the *P* value was less than .05

Part 1 Subject characteristics, such as height and body mass, were compared between groups prior to the treatment intervention using unpaired *t* tests. Gender distribution, nature of condition, area of symptoms, previous physiotherapy treatment, and the inclusion exercise therapy were compared with a nonparametric statistics. Duration of symptoms (years), however, was analyzed with a nonparametric test, considering the positively skewed nature of the data. Outcome measures following the 4-week treatment intervention period were compared between the 2 groups using an analysis of covariance according to the general linear model, with group (2 levels: CG and SETG) as main factor, prestest measurements as a covariate, and posttest measurements as dependent variable.

Part 2 RMQ/RMDQ-HK data were collected for the SETG immediately after and at 3, 6, and 12 months following the treatment intervention period. As follow-up information was not available for some participants, a sensitivity analysis with 4 intention-to-treat analyses was conducted to evaluate the retention of treatment effect. First, missing data of all randomized subjects were handled with the ''last observation carried forward'' (LOCF) imputation method and analyzed with a repeated-measures ANOVA on the different periods that data were collected, followed by post hoc analyses using Fisher's least significant difference test. To verify the robustness of the conclusions of the analysis, 3 intention-to-treat analyses were conducted with 3 alternative approaches. The ANOVAs were carried out for the subjects with a complete data set only, and then the worst-case value was imputed to the missing data, and finally the best-case value. Post hoc analyses were once again conducted using the Fisher least significant difference test.

RESULTS

Subjects

Subjects were recruited over a 4-month period. The treatment intervention took place over a 4-week period from the time of randomization. Analysis indicated no significant difference between the groups regarding baseline characteristics (Table 1). The study sample represented a population of longstanding LBP conditions with the median duration of symptoms in the CG (n = 18) and SETG (n =

Figure 3. Static posture training was followed by training the control of a variety of movement patterns involving hip extension.

21) at 9 years (range, 1-20 years) and 5.5 years (range, 0.5-27 years), respectively. Twenty percent of the entire subject group described their LBP condition to be one of a recurring nature and 80% of the subjects described their condition to be of a chronic, persistent nature. Ninety percent of all subjects had received previous physiotherapy intervention and 74% of those interventions had included exercise therapy.

All subjects in the main study completed the 4-week treatment intervention according to the study protocol and questionnaire data were collected for analysis from all subjects in the main study. Response rate to posttreatment intervention questionnaires in part 2 was 86% at 3 months, 57% at 6 months, and 62% at 12 months (Figure 1).

Treatment Efficacy (Part 1)

After adjusting for measurements at pretest, there was a significant reduction in average pain intensity (P = .002) and in functional disability (P = .023) in the SETG following the treatment intervention period (Table 2). No significant interactions between pretreatment and group were detected for either test. The means and adjusted means and standard errors of the mean for the SETG and CG pretreatment and posttreatment intervention period are depicted graphically in Figures 5 and 6. The posttest adjusted mean in the SETG was 2.0 (95% CI, 1.3 to 2.7) RMQ/RMDQ-HK points compared to a posttest adjusted mean in the CG of 3.2 (95% CI, 2.5 to 4.0) RMQ/RMDQ-HK points. The posttest adjusted mean in pain intensity in the SETG was 18.3 (95% CI, 11.8 to 24.8) NRS points, as compared to 33.9 (95% CI, 26.9 to 41.0) NRS points in the control group.

Retention of Treatment Effect (Part 2)

Retention of treatment effects was examined in the SETG for RMQ/ RMDQ-HK data collected at 3, 6, and 12 months following the completion of the main study (Table 3).

The first intention-to-treat analysis, using LOCF, revealed significant improvements in RMQ/ RMDQ-HK scores over the 12-month period (P<.01) (Figure 7). Post hoc analysis showed a significant difference between pretreatment and posttreatment, and pretreatment and the 3 follow-up periods. Data for the posttreatment differed from the 3- and 6-month periods, but not from the 12-month period. However, no differences were found among the 3 follow-up periods. The analysis suggests that treatment effects were not only retained over time but that the functional disability score decreased further following the completion of the treatment intervention up until 3 months. From 3 months to 12 months, the effects seem to be maintained, although these results should be considered with caution, knowing the lack of significant difference between posttreatment results and the 12-month follow-up.

The other 3 intention-to-treat analyses supported, for the most part, the results found. Significant improvements were found for the group of subjects with a complete data set (P<.01) and for the data set with best-case value imputed to the missing data (P<.01). Post hoc tests also showed similar results,

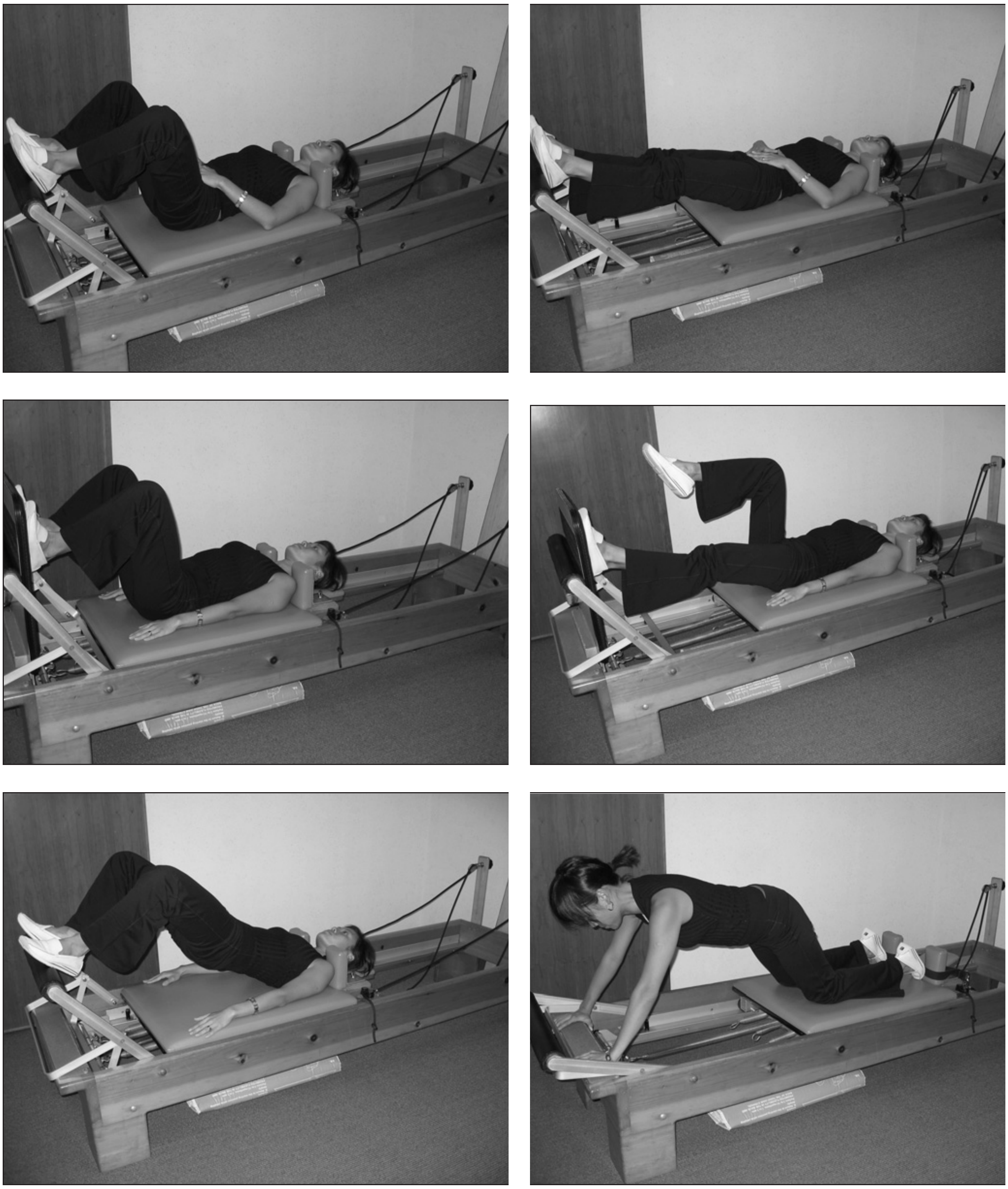

Figure 4. Training progressed on the Pilates Reformer initially involving weight-bearing movements in a lumbar-pelvic neutral position. If tolerated, more non–weight-bearing movements and control of postures out of neutral were introduced.

with the exception that the best-case method did not find a difference between the posttreatment and the 12-month period. When the worst-case value was imputed to the missing data, the results from the analysis did not show a difference between the periods ($P = .12$).

DISCUSSION

The main finding of this study was that a program of specific exercise directed at retraining neuromuscular control, provided by a physiotherapist, and based on the Pilates method was more effica-

RESEARCH REPORT

TABLE 2. Pretest means (SEM) and adjusted posttest means for functional disability and pain intensity for the specific-exercise-training group and the control group.

Outcome Measures	Control Group (n = 18) Pretreatment	Control Group (n = 18) Posttreatment	Specific-Exercise-Training group (n = 21) Pretreatment	Specific-Exercise-Training group (n = 21) Posttreatment	*P* Value*
Functional disability	4.2 (0.8)	3.2 (0.4)	3.1 (0.6)	2.0 (0.3)	.023
Pain intensity score	30.4 (4.2)	33.9 (3.5)	23.0 (3.9)	18.3 (3.2)	.002

* Comparison of posttest scores using pretest scores as covariate.

cious in reducing pain intensity and functional disability levels when compared to usual care. In this study there were significant improvements in mean average pain intensity and in functional disability levels in the SETG following treatment that were not apparent in the CG. Both groups completed the study and compliance was high, with 100% attendance at scheduled clinic appointments. Although compliance with the home protocol was not measured, it was monitored on a log, and a verbal report from the treating physiotherapist reported good compliance in general. The ability to exercise without pain, the opportunity to practice at home, and the quick changes in pain and carryover to function relative to previous chronic condition were reported as important motivating factors for compliance.

The results of this study are in agreement with the conclusion of a systematic review of the literature[45] and the findings by O'Sullivan et al[25] and Lindgren et al.[20] These investigators found that a training approach that followed the principles of segmental stabilization and neuromuscular control was effective in reducing pain[20,25] and disability[25] in a group of individuals with chronic LBP related specifically to radiological instability. The current study demonstrates that an exercise training approach similarly addressing neuromuscular control mechanisms is effective in decreasing pain and improving function in an identified group with nonspecific chronic LBP when compared to a control group. The subjects in the O'Sullivan et al[25] study were trained in stabilization exercises designed to enhance local muscular stability of the intervertebral segment. Although the theoretical rationale of training muscle activation and control was similar in both studies, the training approach in the current study necessarily differed and addressed different components of neuromuscular dysfunction. The subjects in the current study did not demonstrate a primary segmental instability but clinically appeared to display problems in control of the muscles thought to stabilize the lumbar-pelvis region during hip extension and loading.[14,38,46] Therefore, in both the home and the clinic protocol, both local and global stabilization strategies were employed. The transversely oriented abdominal muscles, the lumbar multifidi, the diaphragm, and the muscles of the pelvic floor have all been shown to be important for local stabilization.[7,8,10,12] Specific activation of the gluteal muscles was emphasized in this study to assist with global stability of the lumbar-pelvis-hip region during movement. The Pilates Reformer was used to train a variety of functional movement patterns involving hip extension.

In the current study it is not known whether the treatment effect found was due to training the local stability system or from training more general stabilization strategies. Similarly, it is impossible to disassociate the effect of the clinic intervention from the effects of the home intervention.

The subjects in the study reflected a chronic LBP population with a mean duration of symptoms of 8.2 years. Despite chronic symptoms, this group was able to participate in some form of physical activity at a frequency of 3 times per week. Mean initial RMQ/RMDQ-HK scores for both groups fell within the lowest strata (0-9) identified by Stratford et al,[40] suggesting a relatively low level of reported disability. Despite the apparently low disability and moderate activity levels, all subjects continued to report functional restrictions not resolved with previous interventions. It is speculated that this functional limitation was the motivation to continue to seek treatment. All subjects had received treatment in the past and 90% had received previous physiotherapy treatment(s), 74% of which had included exercise therapy. Most of the subjects had seen more than 1 medical specialist over the years and were continuing to seek treatment. There were no differences between the 2 groups in any of these characteristics. This population may represent a significant subgroup of patients with chronic LBP who seek ongoing treatment in the clinic setting and it may be argued that the needs of this group are not adequately met by traditional interventions, identifying a gap in physical medicine service delivery.

It may be argued that a more useful indicator of outcome may be the clinical significance of changes in disability that are identified in a population with low initial RMQ/RMDQ-HK scores. The minimal clinically important difference (MCID) represents the change in function that is important to an individual patient,[4] and it is a function of the initial RMQ scores. Stratford and colleagues[40] have determined

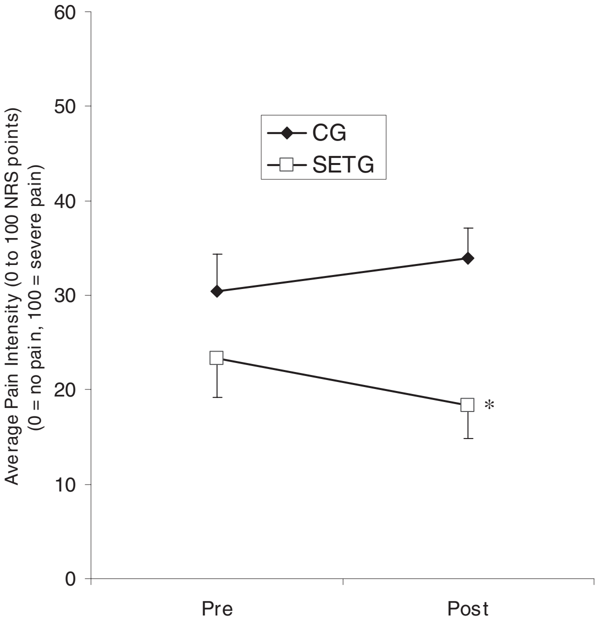

Figure 5. Average pain intensity scores for specific-exercise-training group (SETG) (n = 21) and control group (CG) (n = 18) previous to (pre) and immediately following (post) the treatment intervention period. Values are means (pre) and adjusted means (post) and standard error of the means. *Significant difference of post scores, using pre scores as covariate.

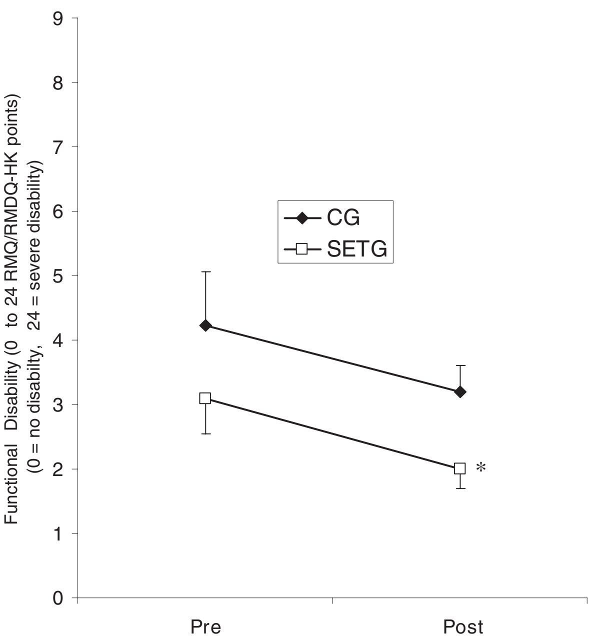

Figure 6. Functional disability scores for specific-exercise-training group (SETG) (n = 21) and control group (CG) (n = 18) previous to (pre) and immediately following (post) the treatment intervention period. Values are means (pre) and adjusted means (post) and standard error of the means. *Significant difference of post scores, using pre scores as covariate.

that a change of 1 to 2 RMQ points is reflective of clinically important changes in subjects whose initial RMQ scores fall within the lowest strata. These results may reflect clinically important changes in functional disability in the group who received specific exercise training in contrast to the group who did not. This lends further support that treatment with specific Pilates-based exercise was more effective than usual care in attaining clinically meaningful changes in functional capacity in our group of subjects. Furthermore, although the changes in functional disability are small when examining a group whose pretreatment and posttreatment scores fall within the lowest strata, it may also be important that no subjects reported an increase in disability throughout the study period.

The subjects in this study fall under the broad classification of nonspecific LBP, although the inclusion criteria were strictly controlled. Classification into more homogenous groups of LBP diagnosis with an intervention tailored according to the needs of the particular group is thought likely to enhance treatment efficacy.[19] Roland and Morris[32,33] suggest that if an intervention is applied indiscriminately to all patients with LBP, it is unlikely that any major effect from treatment will be discerned. Due to the natural history of LBP it was felt necessary to control for some of its variability and the tight inclusion criteria attempted to facilitate homogeneity. All subjects reported unresolved chronic LBP, were physically active, and showed evidence on clinical tests[13,18,38] of altered performance in the muscles about the lumbar-pelvic region, including the gluteus maximus muscle. It was felt that subjects meeting the criteria would be more likely to respond to this treatment approach. Therefore it follows that a limitation of this study may be that results cannot be extrapolated with confidence to chronic LBP conditions outside of the selection criteria for this study, and especially individuals with acute or more disabling LBP. The high percentage of subjects receiving recent care from a health professional, the extent of past physical treatments, and the prior level of exposure to physiotherapy and exercise interventions suggest a response to the intervention itself as opposed to a placebo effect. Additionally, given the chronic nature of the subjects' conditions, it is not likely that the results in the SETG are due to the passage of time.

Similarly, the results in the SETG cannot simply be explained by the introduction of physical training, as only physically active subjects were selected for the study. Subjects in both groups continued with general physical training or advice as prescribed by the independent evaluator and their attending practitioner throughout the duration of the study.

Finally, all of the subjects in the CG were instructed that they would have the opportunity to receive treatment after a 4-week period.

RESEARCH REPORT

TABLE 3. Retention of treatment effects for functional disability for the specific-exercise-training group previous to (prettreatment), immediately following (posttreatment), 3, 6, and 12 months after the treatment intervention for the data collected and with the last observation carried forward intention-to-treat analysis. Values are in means (SEM).

	Pretreatment	Posttreatment	3 Months	6 Months	12 Months
Data collected	3.1 (0.6)	1.7 (0.4)	0.9 (0.4)	0. 4 (0.2)	0.9 (0.6)
n	21	21	18	12	13
Last observation carried forward	3.1 (0.6)	1.7 (0.4)	1.0 (0.4)	1.0 (0.4)	1.1 (0.4)
n	21	21	21	21	21

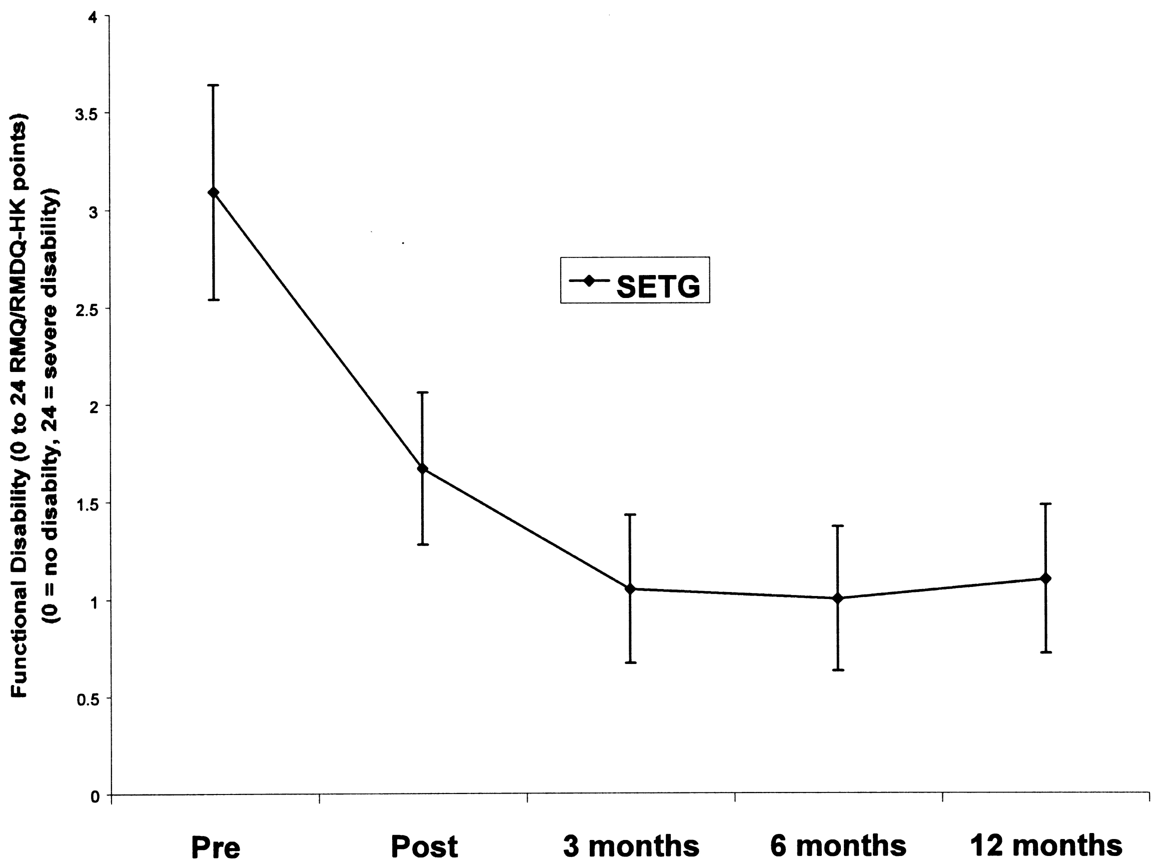

Figure 7. Functional disability scores for specific-exercise-training group (SETG) previous to (pre) and immediately following (post) the treatment intervention and at 3-, 6-, and 12-month follow-up, using the last observation carried forward intention-to-treat analysis. Values are means and standard error of the means (n = 21).

To measure for retention of treatment effect, disability measures were collected from the SETG by questionnaire over a 12-month period following completion of the treatment. Due to the noncompliance of some subjects, the data were analyzed using a sensitivity analysis contrasting 4 intention-to-treat analyses. First the missing data were replaced by the LOCF value. Analysis of these data indicated lower mean functional disability levels were relatively well maintained over the 12-month follow-up period. The biggest changes occurred from the pretreatment to the 3-month follow-up. The disability levels in the treatment group were negligible by the 6-month period and any further changes may not have been of clinical importance.

To evaluate the robustness of these results, the analysis was conducted again but with 3 different methods of handling the missing data. Results were the same with the sample of subjects with a complete data set as well as with the best-case value as imputing method. Results did not show a significant difference, however, when using the worst-case value. Considering this last analysis and the substantial loss of data, the conclusions drawn from the results should be considered with caution.

The lower response rates of 57% for the 6-month and 62% for the 12-month follow-ups may confound the strength of any findings beyond the 3-month follow-up, depending on the reason for dropout from this part of the study. Three subjects were lost following posttesting and 1 subject was lost at the 12-month follow-up. Some of the subjects who did not respond at 6 months did at 12 months and vice versa. An analysis of the group of subjects who did not respond to either or both of the 6- and 12-month follow-ups were shown to have responded similarly to the program on all outcomes compared to the group who provided all follow-up data. These findings would suggest that factors other than a difference in status or treatment response acted to influence participation throughout the follow-up period in this group.

Ability and concomitant disability are relative to individual expectations of function. Also important were unsolicited comments on the questionnaires returned from subjects whose RMQ/RMDQ-HK scores throughout the follow-up period were 0 out of 24. These subjects described a progressive ability to return to activities that had been previously stopped secondary to low back problems that could not be reflected in the RMQ/RMDQ-HK scores. The RMQ/RMDQ-HK may not be sensitive enough to pick up these changes in ability despite the significance for normal function in this population. An alternative, more sensitive measure for this population that has similar measurement properties to the RMQ/RMDQ-HK is not currently available. Such a measure may be useful in demonstrating change in this subgroup of patients with chronic LBP who continue to seek care in physiotherapy.

Clinical Implications

This group of patients may represent individuals seen in physiotherapy clinics and who seek ongoing treatment from healthcare practitioners after subsequent return to normal daily activities despite chronic LBP. The return to normal activities is often with some restrictions and limitations and accompanied with longstanding or recurrent pain. It is this lack of full recovery and ongoing pain that appears to prompt this clientele to seek ongoing treatment. It would appear that a treatment to re-educate neuromuscular control strategies with a structured approach in the clinic environment and complemented with incorporation into a subject-specific functional task is beneficial in the restoration of functional ability levels acceptable to the patient. This specialized exercise approach can be adjunctive to, or may follow other treatment at some point in the continuum of rehabilitation interventions.

In summary, an exercise approach that targets selective muscle recruitment and neuromuscular retraining of stabilization strategies may have a significant effect on pain and disability in a population of active subjects with chronic LBP, with long-lasting effects. A modification of the Pilates method may provide a useful and cost effective treatment modality in the management of such conditions and merits further study.

CONCLUSIONS

The results of the study support the hypothesis that an exercise therapy approach based on the Pilates method and directed at neuromuscular control mechanisms was efficacious in the treatment of a group of individuals with nonspecific chronic LBP. A 4-week treatment intervention was more efficacious than usual care in reducing average pain intensity and functional disability levels, changes were maintained over a 12-month period.

ACKNOWLEDGMENTS

The authors would like to thank Professor Lo Sing Kai, Deakin University and Karine Charpentier, Queen's University, for statistical advice.

REFERENCES

1. Acute Low Back Problems in Adults. Clinical Practice Guideline No. 14. AHCPR Publication No. 95-0642. Rockville, MD: Agency for Health Care and Policy Research, Public Health Service, US Department of Health and Human Services; 1994.
2. Arendt-Nielsen L, Graven-Nielsen T, Svarrer H, Svensson P. The influence of low back pain on muscle activity and coordination during gait: a clinical and experimental study. *Pain*. 1996;64:231-240.
3. Bergmark A. Stability of the lumbar spine. A study in mechanical engineering. *Acta Orthop Scand Suppl*. 1989;230:1-54.
4. Binkley JM. Measurement of functional status, progress, and outcome in orthopaedic clinical practice. *Orthop Div Rev*. 1998;September/October:7-17.
5. Edgerton VR, Wolf SL, Levendowski DJ, Roy RR. Theoretical basis for patterning EMG amplitudes to assess muscle dysfunction. *Med Sci Sports Exerc*. 1996;28:744-751.
6. Health Canada and the Canadian Society for Exercise Physiology. Canada's physical activity guide to healthy active living: Health Canada and the Canadian Society for Exercise Physiology. Ottawa, Ontario, Canada: Health Canada and the Canadian Society for Exercise Physiology; 1998.
7. Hodges PW, Gandevia SC. Activation of the human diaphragm during a repetitive postural task. *J Physiol*. 2000;522 Pt 1:165-175.
8. Hodges PW, Richardson CA. Altered trunk muscle recruitment in people with low back pain with upper limb movement at different speeds. *Arch Phys Med Rehabil*. 1999;80:1005-1012.
9. Hodges PW, Richardson CA. Feedforward contraction of transversus abdominis is not influenced by the direction of arm movement. *Exp Brain Res*. 1997;114:362-370.
10. Hodges PW, Richardson CA. Inefficient muscular stabilization of the lumbar spine associated with low back pain. A motor control evaluation of transversus abdominis. *Spine*. 1996;21:2640-2650.

11. Hong Kong Hospital Authority. Examining reliability, validity and responsiveness of Hong Kong version of Roland-Morris Disability Questionnaire (RMDQ-HK) as an outcome measure of patients with low back pain: a multicentre study. Hong Kong, China: Working Group on Low Back Pain Outcomes Assessment, Coordinating Committee for Physiotherapists, Hong Kong Hospital Authority; 1999.
12. Hungerford B, Gilleard W, Hodges P. Evidence of altered lumbopelvic muscle recruitment in the presence of sacroiliac joint pain. *Spine*. 2003;28:1593-1600.
13. Janda V. Evaluation of muscular imbalance. In: Liebenson C, ed. *Rehabillitation of the Spine: A Practitioner's Manual*. Baltimore, MD: Lippincott, Williams & Wilkins; 1996:
14. Janda V. Muscle weakness and inhibition (pseudoparesis) in back pain syndromes. In: Grieve GP, ed. *Modern Manual Therapy of the Vertebral Column*. New York, NY: Churchill-Livingstone; 1986.
15. Janda V. Muscles, central nervous motor regulation and back problems. In: Korr M, ed. *The Neurobiologic Mechanisms in Manipulative Therapy*. New York, NY: Plenum Press; 1978.
16. Jensen MP, Karoly P, Braver S. The measurement of clinical pain intensity: a comparison of six methods. *Pain*. 1986;27:117-126.
17. Jull GA, Janda V. Muscles and motor control in low back pain: assessment and management. In: Twomey LT, ed. *Physical Therapy of the Low Back*. New York, NY: Churchill-Livingstone; 1987.
18. Kendall FP, Kendall EM, Provance PG. *Muscles: Testing and Function*. 4th ed. Baltimore, MD: Williams & Wilkins; 1993.
19. Leboeuf-Yde C, Lauritsen JM, Lauritzen T. Why has the search for causes of low back pain largely been nonconclusive? *Spine*. 1997;22:877-881.
20. Lindgren KA, Sihvonen T, Leino E, Pitkanen M, Manninen H. Exercise therapy effects on functional radiographic findings and segmental electromyographic activity in lumbar spine instability. *Arch Phys Med Rehabil*. 1993;74:933-939.
21. Lo SK, Lin CF, Phillips BA. On the use and presentation of analysis of variance in rehabilitation research. *Hong Kong Physiother J*. 1998;16:7-12.
22. Maher C, Latimer J, Refshauge K. Prescription of activity for low back pain: What works? *Aust J Physiother*. 1999;45:121-132.
23. Mayer TG, Gatchel RJ. *Functional Restoration for Spinal Disorders: The Sports Medicine Approach*. Philadelphia, PA: Lea & Febiger; 1988.
24. McGill S, Grenier S, Bluhm M, Preuss R, Brown S, Russell C. Previous history of LBP with work loss is related to lingering deficits in biomechanical, physiological, personal, psychosocial and motor control characteristics. *Ergonomics*. 2003;46:731-746.
25. O'Sullivan PB, Phyty GD, Twomey LT, Allison GT. Evaluation of specific stabilizing exercise in the treatment of chronic low back pain with radiologic diagnosis of spondylolysis or spondylolisthesis. *Spine*. 1997;22:2959-2967.
26. Panjabi MM. Clinical spinal instability and low back pain. *J Electromyogr Kinesiol*. 2003;13:371-379.
27. Pool-Goudzwaard AL, Vleeming A, Stoeckart R, Snijders CJ, Mens JM. Insufficient lumbopelvic stability: a clinical, anatomical and biomechanical approach to 'a-specific' low back pain. *Man Ther*. 1998;3:12-20.
28. Rainville J, Hartigan C, Martinez E, Limke J, Jouve C, Finno M. Exercise as a treatment for chronic low back pain. *Spine J*. 2004;4:106-115.
29. Richardson CA, Jull GA. Concepts of rehabilitation for spinal stability. In: Boyling JD, Palastanga N, eds. *Grieve's Modern Manual Therapy of the Vertebral Column*. Edinburgh, UK: Churchill-Livingstone; 1994:705-720.
30. Richardson CA, Jull GA. Muscle control-pain control. What exercises would you prescribe? *Man Ther*. 1995;1:2-10.
31. Richardson CA, Jull GA, Hodges P, Hides J. *Therapeutic Exercise for Spinal Segmental Stabilization in Low Back Pain*. London, UK: Churchill Livingstone; 1999.
32. Roland M, Morris R. A study of the natural history of back pain. Part I: development of a reliable and sensitive measure of disability in low-back pain. *Spine*. 1983;8:141-144.
33. Roland M, Morris R. A study of the natural history of back pain. Part II: development guidelines for trials of treatment in primary care. *Spine*. 1983;8:144-150.
34. Rydeard RA. Die rehabilitation eines elite-triathleten. Trainingstherapie nach dem konzeptder Biokinetik Exercice Technique: ein Fallbericht (Teil 1). *Physiotherapie Fisioterapia*. 2000;4:12-16.
35. Rydeard RA. Die rehabilitation eines elite-triathleten. Trainingstherapie nach dem konzeptder Biokinetik Exercice Technique: ein Fallbericht (Teil 2). *Physiotherapie Fisioterapia*. 2000;5:12-16.
36. Sahrmann SA. Posture and muscle imbalance: faulty lumbar pelvic alignment and associated musculoskeletal pain syndromes. *Orthop Div Rev*. 1992;Nov-Dec:13-20.
37. Siler B. *The Pilates Body*. New York, NY: Random House; 2000.
38. Singer K. Suggestions from the clinic: a new nusculoskeletal assessment in a student population. *J Orthop Sports Phys Ther*. 1986;8:34-41.
39. Spitzer WO. Scientific approach to the assessment and management of activity-related spinal disorders. A monograph for clinicians. *Spine*. 1987;12:S1-S59.
40. Stratford PW, Binkley JM, Riddle DL, Guyatt GH. Sensitivity to change of the Roland-Morris Back Pain Questionnaire: part 1. *Phys Ther*. 1998;78:1186-1196.
41. Tsang RCC. Measurement properties of the Chinese version of the Roland-Morris Disability Questionnaire. *Hong Kong Physiother J*. 2004;22:40-49.
42. US Department of Health and Human Services (USDHHS), Centers for Disease Control and Prevention. Physical activity and health: a report of the Surgeon General. Altanta, GA: USDHHS; 1996.
43. van Tulder M, Malmivaara A, Esmail R, Koes B. Exercise therapy for low back pain: a systematic review within the framework of the cochrane collaboration back review group. *Spine*. 2000;25:2784-2796.
44. van Tulder MW, Koes BW, Bouter LM. Conservative treatment of acute and chronic nonspecific low back pain. A systematic review of randomized controlled trials of the most common interventions. *Spine*. 1997;22:2128-2156.
45. van Tulder MW, Malmivaara A, Esmail R, Koes BW. Exercise therapy for low back pain. *Cochrane Database Syst Rev*. 2000;CD000335.
46. Vleeming A, Pool-Goudzwaard AL, Stoeckart R, van Wingerden JP, Snijders CJ. The posterior layer of the thoracolumbar fascia. Its function in load transfer from spine to legs. *Spine*. 1995;20:753-758.
47. Vogt L, Pfeifer K, Banzer W. Neuromuscular control of walking with chronic low-back pain. *Man Ther*. 2003;8:21-28.