Systematic Review: Strategies for Using Exercise Therapy To Improve Outcomes in Chronic Low Back Pain

Jill A. Hayden, DC; Maurits W. van Tulder, PhD; and George Tomlinson, PhD

Background: Exercise therapy encompasses a heterogeneous group of interventions. There continues to be uncertainty about the most effective exercise approach in chronic low back pain.

Purpose: To identify particular exercise intervention characteristics that decrease pain and improve function in adults with nonspecific chronic low back pain.

Data Sources: MEDLINE, EMBASE, PsychInfo, CINAHL, and Cochrane Library databases to October 2004 and citation searches and bibliographic reviews of previous systematic reviews.

Study Selection: Randomized, controlled trials evaluating exercise therapy in populations with chronic (>12 weeks duration) low back pain.

Data Extraction: Two reviewers independently extracted data on exercise intervention characteristics: program design (individually designed or standard program), delivery type (independent home exercises, group, or individual supervision), dose or intensity (hours of intervention time), and inclusion of additional conservative interventions.

Data Synthesis: 43 trials of 72 exercise treatment and 31 comparison groups were included. Bayesian multivariable random-effects meta-regression found improved pain scores for individually designed programs (5.4 points [95% credible interval (CrI), 1.3 to 9.5 points]), supervised home exercise (6.1 points [CrI, −0.2 to 12.4 points]), group (4.8 points [CrI, 0.2 to 9.4 points]), and individually supervised programs (5.9 points [CrI, 2.1 to 9.8 points]) compared with home exercises only. High-dose exercise programs fared better than low-dose exercise programs (1.8 points [CrI, −2.1 to 5.5 points]). Interventions that included additional conservative care were better (5.1 points [CrI, 1.8 to 8.4 points]). A model including these most effective intervention characteristics would be expected to demonstrate important improvement in pain (18.1 points [CrI, 11.1 to 25.0 points] compared with no treatment and 13.0 points [CrI, 6.0 to 19.9 points] compared with other conservative treatment) and small improvement in function (5.5 points [CrI, 0.5 to 10.5 points] compared with no treatment and 2.7 points [CrI, −1.7 to 7.1 points] compared with other conservative treatment). Stretching and strengthening demonstrated the largest improvement over comparisons.

Limitations: Limitations of the literature, including low-quality studies with heterogeneous outcome measures and inconsistent and poor reporting; publication bias.

Conclusions: Exercise therapy that consists of individually designed programs, including stretching or strengthening, and is delivered with supervision may improve pain and function in chronic nonspecific low back pain. Strategies should be used to encourage adherence. Future studies should test this multivariable model and further assess specific patient-level characteristics and exercise types.

Ann Intern Med. 2005;142:776-785. www.annals.org
For author affiliations, see end of text.

Exercise therapy is widely used as a treatment for low back pain. In our accompanying paper in this issue (1), we present the results of a systematic review, conducted within the framework of the Cochrane Collaboration. We assessed the effectiveness of exercise therapy for reducing pain and disability in adult nonspecific acute, subacute, and chronic low back pain compared with no treatment and other conservative treatments. We concluded that exercise therapy seems to be effective at slightly decreasing pain and improving function in adults with chronic low back pain, particularly in health care populations. In subacute low back pain, evidence suggests that a graded-activity program improves absenteeism outcomes, although evidence for other types of exercise is unclear. In acute low back pain, exercise therapy is as effective as either no treatment or other conservative treatments.

Exercise therapy encompasses a heterogeneous group of interventions that vary in type, intensity, frequency, and duration of exercise and the setting in which it is provided. There continues to be uncertainty about the most effective approach (2), and the literature on the hypothesized mechanism of the effect of exercise interventions provides little guidance (3). Better understanding of important characteristics of the intervention would allow us to more fully inform clinical practice and future research in the application of exercise therapy. However, standard methods of meta-analysis are not ideal because they necessitate the exclusion of correlated data from trials investigating several treatment groups within studies and cannot include information from trials without comparison groups. We aimed to identify particular exercise intervention characteristics that decrease pain and improve function in adults with nonspecific chronic low back pain.

See also:

Print
Editors' Notes 777
Related article 765
Summary for Patients I-72

Web-Only
Conversion of figures and tables into slides

METHODS

Review Methods

Our search strategy included a computerized search of the electronic databases MEDLINE and EMBASE (up to October 2004), PsychInfo and CINAHL (1999 to October 2004), and the Cochrane Central Register of Controlled Trials (Issue 3, 2004). We searched citations and screened cited references of exercise reviews and contacted content experts for additional trials. We did not restrict the searches or inclusion criteria to any specific languages. We followed a standard protocol for study selection and data abstraction (4). Two reviewers independently assessed study eligibility, data extraction, trial quality, and clinical relevance. We used consensus and a third reviewer, if needed, to resolve disagreements. We extracted the data onto pretested standardized forms.

Further details on the strategies for the search and identification of studies have been reported elsewhere (1). We included randomized, controlled trials if they investigated exercise therapy as an intervention for nonspecific low back pain, regardless of the comparison group or groups. Outcomes of interest were pain, function, return to work or absenteeism, and global improvement. We present analysis and results of the subgroup of 43 trials (3907 participants) that were conducted in the populations with chronic low back pain (lasting longer than 12 weeks) and adequately report the outcomes of pain and function. We measured pain and function as continuous variables, and we placed each study's results on a common 0- to 100-point scale to facilitate comparison and interpretability of the syntheses. On the basis of current literature on minimal clinically important differences, we considered a 20-point (out of 100 points) improvement in pain (5) and a 10-point (out of 100 points) improvement in functioning outcomes (6) to be clinically important. We used data from the available follow-up period closest to 6 weeks after randomization for all analyses.

Exercise Intervention Characteristics

We identified important intervention characteristics a priori, with the assistance of clinical experts. We characterized exercise interventions by the exercise program design, delivery type, dose or intensity, inclusion of additional interventions, and the types of exercises included. When necessary, we contacted authors for additional information.

We categorized design of the exercise therapy program as "individually designed," in which the treating therapist completed a clinical history and physical examination and delivered an exercise program specifically designed for the individual participant; "partially individually designed," in which the exercise program included the same type of exercises but varied in intensity, duration, or both; or "standard design," in which a fixed exercise program was delivered to all participants.

We characterized delivery type of the exercise therapy as follows: 1) home exercises only, in which the participants met initially with therapists, then participated in the exercise program with no supervision or follow-up; 2) supervised home exercises, in which the participants met initially with therapists, participated in the exercise program, and had follow-up with their therapist at least every 6 weeks; 3) group supervision, in which participants attended exercise therapy sessions with 2 or more participants; and 4) individual supervision, in which participants received one-on-one intervention or supervision. We classified exercise therapy programs that included more than 1 type of delivery according to their main delivery type.

We assessed dose or intensity of the exercise therapy by considering the duration and number of treatment sessions. If the exercise program included a home exercise component and study adherence information was not available, we used a best estimate of intervention dosage. We computed the best estimate for supervised home exercise programs (those with provider follow-up at least every 6 weeks) by using an adherence rate of 75% of the recommended time and number of sessions. For home exercise programs without follow-up, we used an adherence rate of 50% of the recommended time and number of sessions. We selected these rates from the observed adherence rate for home exercises, according to daily diary recordings (7) and therapist (7, 8) and patient (8–10) reporting of adherence to the prescribed programs. We dichotomized the dose of each exercise intervention to facilitate interpretation of results—high-dose exercises were those with 20 or more hours of intervention time, and low-dose exercises were those with less than 20 hours of intervention time. Twenty hours was the mean dose of the exercise interventions and seemed to distinguish exercise groups with respect to intensity. Sensitivity analyses using 15- and 25-hour cutoff points resulted in less than a 10% change in the grouping of studies.

Context

Which types of exercise therapy are most beneficial to patients with nonspecific chronic low back pain?

Contribution

This Bayesian meta-regression of 43 trials suggests that the most effective exercises for improving pain and function in adults with chronic low back pain are stretching and strengthening, respectively. Exercise performed over longer periods of time seemed more effective than exercise performed less than 20 hours total. Supervised programs that were individually tailored seemed to be more effective than other delivery modes.

Cautions

Trials used various measures to assess pain and function, and many were small and of low quality.

–The Editors

We considered additional treatment other than exercise therapy in the study groups to be a factor associated with effectiveness. We documented the use of and the specific type or types of additional treatments. Because several different additional treatments were used and there is uncertainty about effectiveness, we did not assess the effect of different additional treatment types.

We recorded the types of exercises included in the exercise intervention groups. Muscle-strengthening exercises were interventions that primarily involved muscle contraction, were usually repeated many times, and were limited to specific muscle groups that aimed to increase muscle cross-sectional area and strength (11). Stretching exercises aimed to increase the amount of movement of a specific joint or series of joints and lengthen the presumably contracted or shortened muscles (11). Coordination exercises included training and used specific movements to improve the coordination or proprioception of movements and muscle function (12, 13). Mobilizing or flexibility exercises were repeated exercises, using controlled movements throughout a joint's normal range of motion. We noted specific extension mobilization and flexion mobilization exercises; these included controlled movements in these specific directions only. Aerobic exercises or general physical fitness included "whole-body" interventions that were added to normal activities of daily living and prescribed in a specified dose, for example, specific programs of walking, swimming, or cycling. We also identified other specific exercise therapies: McKenzie exercise therapy (14), functional restoration or the David Beck Clinic program (15, 16), Cesar therapy (17), and Mensendieck therapy (18). Because only a few studies were available, we could not assess these specific exercise therapies separately.

Statistical Analysis

We used meta-analysis and meta-regression analyses to synthesize the randomized, controlled trial data on the effect of exercise treatment and to assess the effect of exercise intervention characteristics. The outcomes in all analyses were the group-specific mean follow-up outcome measures. This allowed us to use data from several groups within a study and to assess the importance of predictors at the group or study levels (19). As usual in meta-analysis, we treated the reported within-group variances as true variances and appropriately divided them by group sample sizes to calculate variances of the means.

We initially investigated the exercise treatment effect in a random-effects analysis of any exercise versus no exercise. Similarly, we assessed the independent influence of each level of exercise intervention characteristics. For example, we compared groups receiving less than 20 hours of exercise to groups receiving 20 or more hours. Next, to simultaneously adjust for several exercise intervention characteristics, we used a Bayesian multivariable random-effects meta-regression, which allows clustering of study groups within trials. Our model is similar to examples presented in books by Spiegelhalter and colleagues (20) and Gelman and colleagues (19). In our analysis, we have studies with several comparison or treatment groups—the mean in a particular group j of a study i is given by $[\mu_i + \theta_{ij}]$, where μ_i is the random-effect mean in the no-treatment comparison group for study i (even though there may not be a group receiving no treatment) and θ_{ij} is the effect of the multifaceted intervention in group j of study i. The intervention effect θ_{ij} is the sum of the contributions from characteristics of group j in study i. We modeled 9 characteristics: 1) any exercise treatment group—exercise group versus comparison group; exercise program design—2) individually designed or 3) partially individually designed versus standardized; exercise delivery type—4) supervised home exercises, 5) group supervision, or 6) individual supervision versus unsupervised home exercises; 7) dose or intensity of exercise intervention—high-dose or -intensity versus low-dose or -intensity; 8) additional conservative treatment—yes versus no; and 9) an interaction between any exercise and the use of an additional conservative treatment type. We defined the reference exercise intervention as a standardized design delivered at home with low intensity and with no additional conservative treatment. The intervention effect is then

$$\theta_{ij} = \beta_1 X_{1(ij)} + \beta_2 X_{2(ij)} + \beta_3 X_{3(ij)} + \beta_4 X_{4(ij)} + \beta_5 X_{5(ij)} + \beta_6 X_{6(ij)} + \beta_7 X_{7(ij)} + \beta_8 X_{8(ij)} + \beta_9 X_{9(ij)}$$

where the subscripts 1 to 9 refer to the 9 characteristics.

Data were inadequate for investigation of the effect of exercise type within the full multivariable model. We used smaller regression models, including only the exercise variable (exercise group vs. comparison group) and the 6 categories of exercise types, to estimate the effects of each type and rank them according to outcome improvement at follow-up. Our Bayesian model allows us to estimate the ranks (from best to worst) of the exercise types, as well as the uncertainty in the rankings.

We present the posterior mean for the estimated effect of each intervention characteristic and display the uncertainty around the estimate by using a 95% credible interval (CrI). Using the multivariable model, we predicted the mean outcome for a group receiving the best level of each intervention characteristic. Comparing this mean with groups that received no treatment or other conservative treatments, we calculated the probabilities of observing clinically meaningful improvement. We repeated this modeling process separately for pain and function outcomes.

We used SAS, version 9.1 (SAS Institute, Inc., Cary, North Carolina), for descriptive analyses and WinBUGS, version 1.4.1 (WinBUGS Package, Imperial College and Medical Research Council, London, United Kingdom), for the Bayesian meta-analysis and regression modeling. For all Bayesian analyses, we used diffuse, noninformative priors, allowing the results to be driven by the data, while using the Bayesian "machinery." For regression parameters, we used diffuse priors (uniform [0, 100] for parameters constrained to be positive in the range of 0 to 100 and normal [mean = 0; variance = 10^6]). For SD terms, we used a uniform distribution covering all reasonable values (uniform [0, 25]). The software package WinBUGS uses Markov chain Monte Carlo with Gibbs sampling to make inferences (21). After a burn-in of 10 000 updates, we performed 3 chains with 10 000 iterations and assessed convergence. Complete models and WinBUGS code are available on request.

Sensitivity Analyses

To be included in the analyses, studies had to report means or median follow-up outcomes for study groups. To use all available means, we imputed variances (where missing) by using the average variance from other included studies. We conducted sensitivity analyses to assess the effect of excluding studies reporting median values and excluding studies that did not adequately present variances. Because there were not enough trials, we could not investigate the effect of study population source and study quality assessment in the multivariable model. These variables were important in our accompanying paper, in which we discuss their implications (1).

Role of the Funding Sources

The personal funding source for an author, the Canadian Institutes of Health Research (postdoctoral fellowship) and the Canadian Chiropractic Research Foundation, had no role in the collection, analysis, or interpretation of the data or in the decision to submit the manuscript for publication.

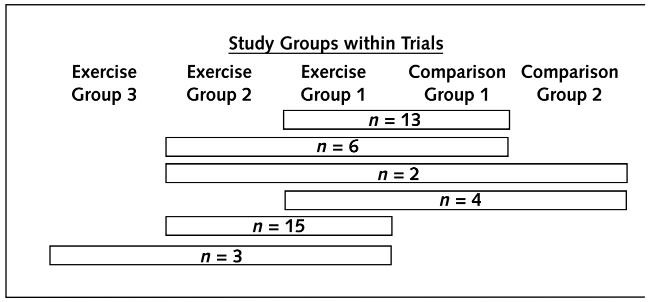
RESULTS

Description of Included Studies

In our accompanying paper (1), we describe the study selection process, characteristics, and results of all trials included in our systematic review (1). For our current analysis, 43 studies in chronic low back pain populations provide data on 72 independent exercise groups and 31 nonexercise comparison groups (7, 10, 12, 14–18, 22–56). Many trials included several exercise therapy groups, and some included several comparison groups. **Figure 1** shows the breakdown of trial designs, and **Figure 2** shows the pain and function outcome results from each study group. We included all study groups with usable data in our current analysis.

Table 1 summarizes the characteristics of the interventions in the included exercise groups. Characteristics of the exercise interventions were unclear for some exercise groups (6% for exercise program design, 8% for delivery type, and 7% for dose). The exercise groups were heterogeneous in their exercise interventions. The most commonly investigated exercise programs were of standard design, were delivered with individual or group supervision, and were of low dose or intensity. Strengthening exercises

Figure 1. **Breakdown of design of 43 included trials.**



Numbers of exercise therapy and comparison groups are indicated. For example, 13 trials included 1 exercise group and 1 comparison group, and 15 trials compared 2 types of exercise groups.

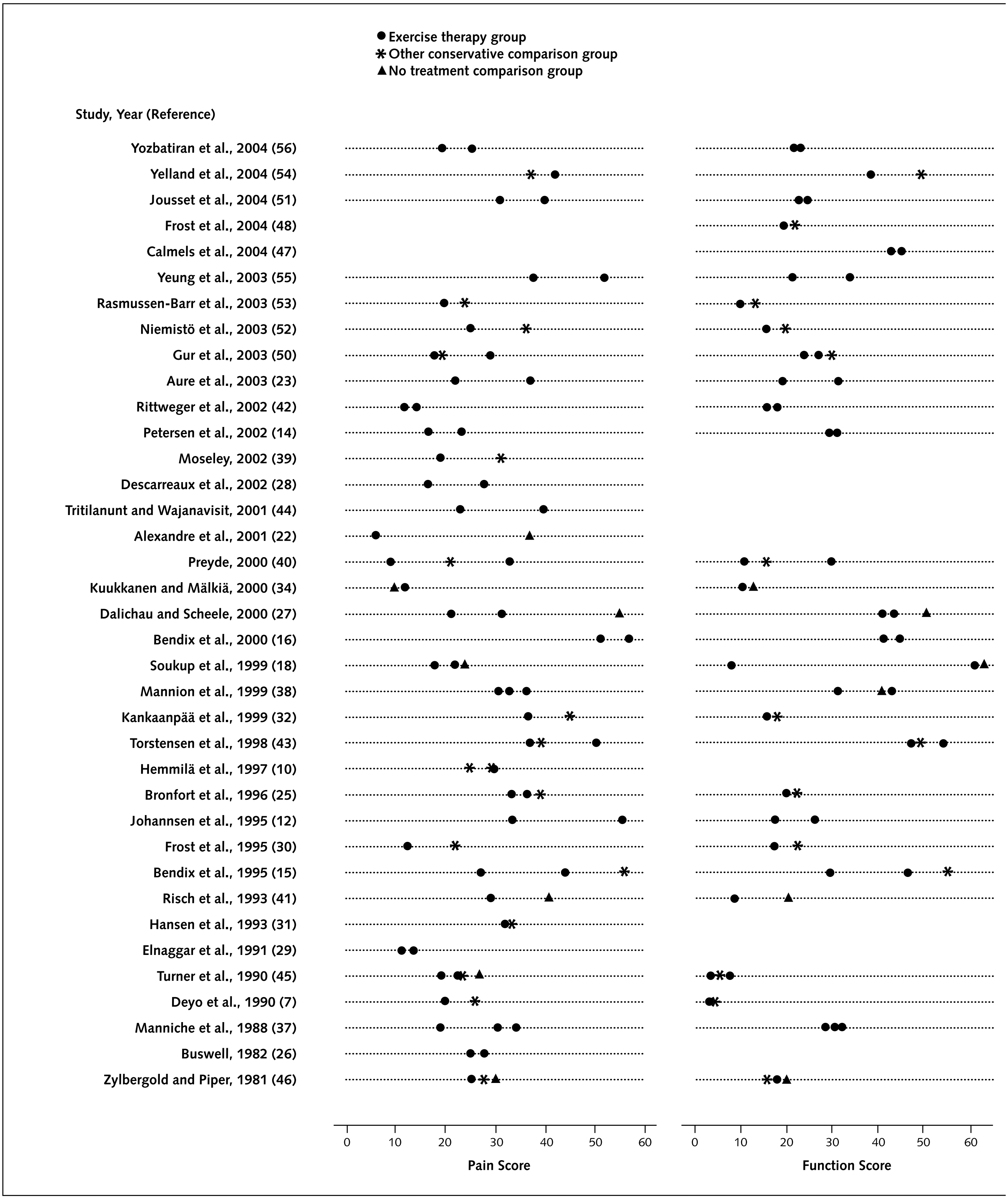
were the most common type of exercise investigated in the trials. About half of the studies used additional conservative interventions along with exercise therapy and included education or advice to stay active, nonsteroidal anti-inflammatory drugs (NSAIDs), manual therapies, and passive modalities.

Exercise Therapy Interventions

Thirty-five randomized, controlled trials that included 59 exercise and 26 comparison groups (3226 participants) provided adequate data for modeling exercise intervention characteristics for pain outcomes. Twenty-nine trials that included 50 exercise and 21 comparison groups (2947 participants) were available for function outcomes. The mean follow-up time for studies contributing data was 9.1 weeks (95% CI, 7.1 to 11.0 weeks). The overall exercise treatment effect in the univariate analysis, when intervention characteristics are not included, was 3.4 points (95% credible interval [CrI], 2.0 to 4.7 points) for improvement in pain outcomes and 1.2 points (CrI, 0.5 to 1.9 points) for improvement in function outcomes (**Table 2**). We found that individual exercise characteristics were important in contributing to unadjusted improvement in pain and function outcomes, including individually designed programs, high-dose exercises, and the addition of other conservative treatment (**Table 2**).

Multivariable random-effects meta-regression controlled for confounding among the various intervention characteristics. In our analysis, the reference treatment was an exercise program of standard program design, delivered home exercises only, was low dose, and had no additional interventions. This model found improved pain and function scores for 1) individually designed exercise programs; 2) supervised home exercises with therapist follow-up, group, and individually supervised exercise delivery strategies; and 3) high-dose or high-intensity exercise programs. We found an additive effect of additional conservative care to the exercise effects, and we did not observe an interaction (**Table 3**). Multivariable modeling of outcomes with an exercise program using the best levels of these intervention characteristics (an individually designed, high-dose ex-

Figure 2. **Pain (*left*) and function (*right*) outcomes for study groups within each trial.**



Exercise, conservative comparison, and no-treatment comparison groups are noted. Results for each group represent mean outcome scores at earliest follow-up period on a 100-point scale.

Table 1. **Characteristics of the Interventions Delivered in the 72 Exercise Groups from 43 Included Randomized, Controlled Trials**

Characteristic	Groups, *n (%)*
Exercise program design	
Individually designed	9 (13)
Partially individually designed	26 (38)
Standard	33 (49)
Primary delivery format	
Home exercises	11 (17)
Supervised home exercises with follow-up	4 (6)
Group supervision	25 (38)
Individual supervision	26 (39)
Dose of intervention	
High-dose (≥20 h)	18 (26)
Low-dose (<20 h)	51 (74)
Other additional interventions	
Additional conservative intervention	36 (50)
No additional intervention	36 (50)
Types of exercise (may include > 1 type)	
Strengthening	43 (60)
Stretching	25 (35)
Aerobic	18 (25)
Coordination	4 (6)
Mobilizing	13 (18)
Other specific types or mixed (>3 types)	10 (14)

ercise program delivered through supervised home exercises with regular practitioner follow-up) is expected to demonstrate improvement in pain scores (18.1 points [CrI, 11.1 to 25.0 points] compared with no treatment, and 13.0 points [CrI, 6.0 to 19.9 points] compared with other conservative treatment) (**Figure 3**, *top*) and function scores (5.5 points [CrI, 0.5 to 10.5 points] compared with no treatment, and 2.7 points [CrI, 1.7 to 7.1 points] compared with other conservative treatment) (**Figure 3**, *bottom*). The probability that this represents a clinically important improvement for pain and function outcomes is 29% and 4%, respectively, compared with no treatment, and 3% and 1%, respectively, compared with other conservative treatments.

Figure 4 shows the rank of specific types of exercise therapy according to improvement in pain and function outcomes. Stretching demonstrated the largest improvement for pain outcomes, while strengthening exercises ranked most effective for improving function outcomes.

Sensitivity Analyses

Sensitivity analyses excluding studies that presented median scores and those with incomplete variance data resulted in small changes to the adjusted coefficients in the multivariable analysis and small increases in the size of the credible regions of the posterior means (results available on request). Our conclusions remain unchanged.

DISCUSSION

We performed a novel exploratory meta-analysis of important intervention characteristics by using data from a systematic review of randomized, controlled trials of exercise therapy. The results of the traditional meta-analysis presented in our accompanying paper (1) showed only small improvements in pain and functioning when combining all exercise therapies. However, our current meta-analysis showed that clinically meaningful improvements in pain are possible when specific intervention characteristics are included. The most effective strategy seems to be individually designed exercise programs delivered in a supervised format (for example, home exercises with regular therapist follow-up) and encouraging adherence to achieve

Table 2. **Independent Effect of Exercise Treatment and Each Group Intervention Characteristic for Pain and Function Outcomes***

Independent Variables	Improvement in Pain (95% CrI), *points*	Improvement in Function (95% CrI), *points*
Treatment effect (exercise group)†	3.4 (2.0 to 4.7)	1.2 (0.5 to 1.9)
Exercise program design		
Individually designed	8.4 (4.8 to 11.9)	1.7 (−0.2 to 3.6)
Partially individually designed	0.6 (−1.9 to 3.2)	1.3 (−0.2 to 2.7)
Standardized	−4.3 (−6.6 to −1.9)	−2.0 (−3.4 to −0.6)
Exercise delivery type		
Home exercises only	−7.5 (−10.8 to −4.3)	−2.0 (−4.7 to 0.7)
Supervised home exercises	6.5 (1.0 to 11.9)	−2.2 (−3.7 to −0.7)
Group supervision	1.8 (−0.9 to 4.5)	0.9 (−0.6 to 2.5)
Individual supervision	1.6 (−0.8 to 4.0)	2.2 (0.6 to 3.7)
Exercise dose or intensity		
High-dose (≥20 h)	2.6 (−0.4 to 5.5)	1.4 (0.7 to 3.5)
Additional conservative treatment		
Additional treatment included	5.3 (3.6 to 7.1)	2.1 (0.7 to 3.7)

* Pain outcomes: 35 trials and 85 study groups; function outcomes: 29 trials and 71 study groups. Outcomes are change on 0- to 100-point scale; positive values indicate improvement in pain and functioning associated with the characteristic. CrI = credible interval.
† Univariate modeling of exercise treatment effect.

Table 3. **Multivariable Meta-Regression Model for Exercise Group Intervention Characteristics and Pain and Function Outcomes***

Independent Variables	Improvement in Pain (95% CrI), *points*	Improvement in Function (95% CrI), *points*
Exercise program design (reference group: standardized program)		
Individually designed	5.4 (1.3 to 9.5)	0.7 (−2.5 to 3.9)
Partially individually designed	0.1 (−3.4 to 3.6)	1.1 (−2.0 to 4.2)
Exercise delivery type (reference group: home exercises only)		
Supervised home exercises	6.1 (−0.2 to 12.4)	1.3 (−2.1 to 4.8)
Group supervision	4.8 (0.2 to 9.4)	1.5 (−2.2 to 5.3)
Individual supervision	5.9 (2.1 to 9.8)	3.2 (−0.6 to 4.8)
Exercise dose or intensity (reference group: low-dose [<20 h])		
High-dose (≥20 h)	1.8 (−2.1 to 5.5)	2.1 (−0.6 to 4.9)
Additional conservative treatment (reference group: no additional treatment)		
Additional treatment included	5.1 (1.8 to 8.4)	2.8 (0.6 to 4.9)
Interaction: exercise group and additional treatment	0.1 (−4.0 to 4.1)	−1.1 (−3.9 to 1.7)
Remaining treatment effect	−0.3 (−4.6 to 4.0)	−0.2 (−3.4 to 3.0)

* Pain outcomes: 35 trials and 85 study groups; function outcomes: 29 trials and 71 study groups. Outcomes are change on 0- to 100-point scale; positive values indicate improvement in pain and functioning associated with the characteristic relative to the reference group indicated. CrI = credible interval.

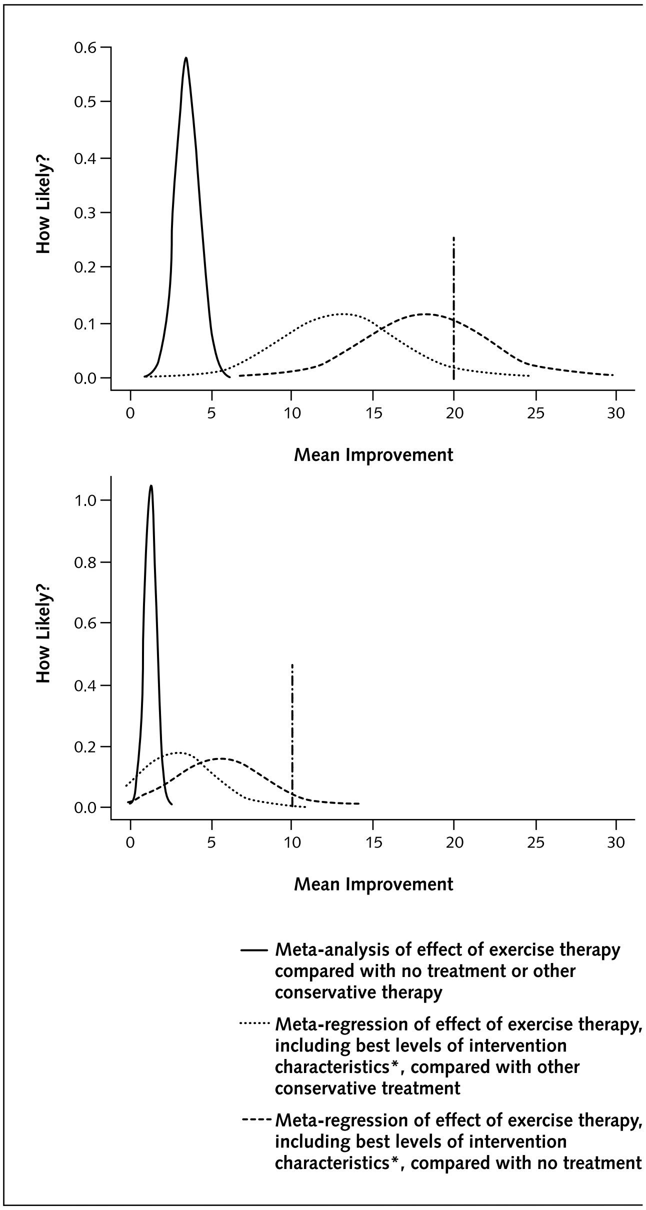
high dosage. Adding other conservative treatment, such as advice to stay active, NSAIDs, or manual therapy, also resulted in improved pain and function outcomes. We found that stretching and muscle-strengthening exercises were the best types of exercises for improving pain and function, respectively.

Our study has several notable strengths and some limitations. We planned our analyses a priori, developed the model through discussions with clinical experts, and fitted the full model. We based the data included in our study on a comprehensive systematic review of the literature conducted within the framework of the Cochrane Collaboration and included many randomized, controlled trials. Our study demonstrates new methods that can be used in systematic reviews, which made full use of available study data to compare various group-level characteristics in a multivariable meta-regression. Furthermore, the analysis using Bayesian methods allowed for a meaningful and informative presentation of results for clinicians and researchers, including direct probability statements and prediction of future study results. Important limitations of our study are similar to those for all systematic reviews: incomplete and inadequate reporting in the primary studies and poor-quality trials. Inadequate reporting prevented the assessment of important return-to-work or absenteeism and global improvement outcome measures. Also, not enough studies were available in our current investigation to include a measure of study quality in the multivariable analysis. In our accompanying paper (1), we found that only 6 of the 43 trials in chronic low back pain populations were rated as high-quality, according to our 4 key internal validity items. We found that the observed mean effect was overestimated in lower-quality studies (1). Our current study would probably be affected in the same way. Also, we found potential publication bias, which may have resulted in an overestimation of the effectiveness of exercise therapy in this population (1). Whether poor-quality studies and publication bias would affect the relationship between intervention characteristics and the resulting model is unclear. Although we used characteristics of the exercise interventions to explain heterogeneity between exercise treatment groups, we could not include a random-effects term in the model to account for possible additional heterogeneity in the exercise effect. Finally, we did not consider potentially important patient-level characteristics, such as age or baseline disability. However, the availability of only group-level data resulted in no important variation in these characteristics across studies. Meta-analysis of individual patient data may be a useful analytic strategy to assess in the future (57).

Despite these limitations, our study provides additional useful information from trials for clinicians and policymakers on the relative effectiveness of characteristics of exercise therapy. However, caution is required when applying these results in clinical practice. Regression to the mean may hide important patient-level characteristics in the primary studies, and randomized, controlled trials may not reflect everyday practice. Therefore, clinicians need to use clinical judgment in applying our results to individual patients.

To our knowledge, the characteristics of exercise therapy have not been previously analyzed with meta-regression analyses. Earlier reviews have considered exercise characteristics as part of narrative summaries and have reported individual study findings (11, 58, 59). A previous practice guideline review on rehabilitation interventions for low back pain (60) considered treatment effects in subgroups of studies according to exercise types. They used meta-analysis and reported good evidence to support stretching, strengthening, and mobility exercises for chronic low back pain. No study investigated what we have found to be the best intervention strategy and reported on pain or function

Figure 3. **Probability functions based on data from systematic review.**

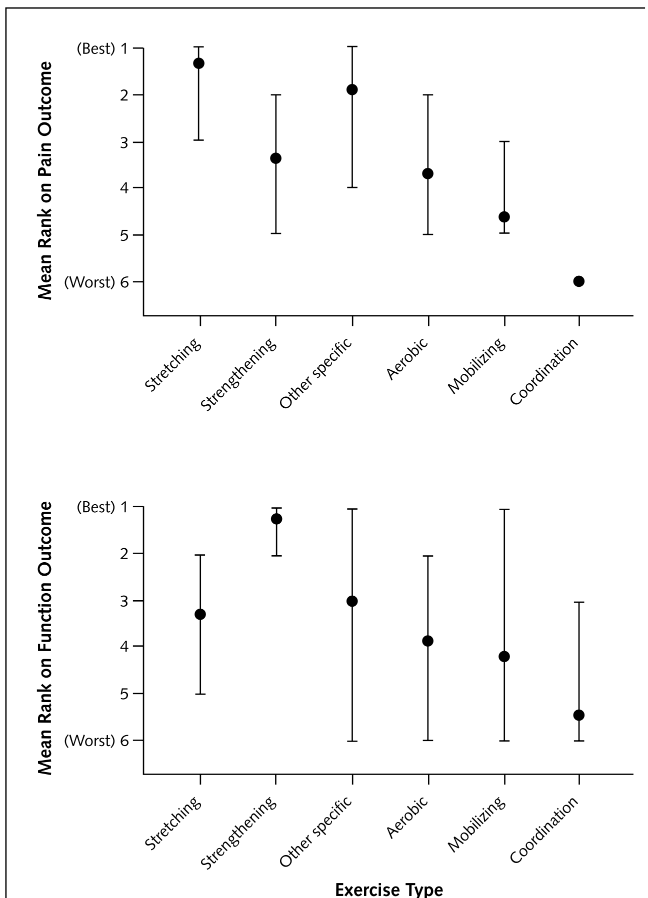


Meta-analysis includes all relevant studies of exercise therapy. Results represent mean improvement scores in pain outcome (*top*) and function outcome (*bottom*) at earliest follow-up on a 100-point scale. The area to the right of the vertical line indicates clinically important improvement. *Meta-regression modeling of best levels of intervention characteristics includes individually designed exercise treatment program, supervised home exercises with follow-up, high-intensity or high-dose intervention, and additional conservative intervention (see text for detailed description).

outcomes. The predicted outcome based on the "best" exercise intervention strategy that we identified in our multivariable model will probably slightly overestimate the true effect. A future randomized, controlled trial should investigate whether our summary accurately reflects what will happen in a future trial. Finally, our study presents a novel analytic strategy for dealing with the common problem of several correlated study groups and characteristics at the study group level. These methods used the available data better and could be used in future systematic reviews.

In our accompanying systematic review (1), we concluded that exercise therapy is effective at slightly decreasing pain and improving function in chronic low back pain populations. Our current investigation used a novel analytic strategy and concluded that characteristics of the exercise intervention are associated with outcomes. The most effective strategy seems to be delivering individually designed exercise programs in a supervised format (for example, home exercises with regular therapist follow-up), encouraging adherence to achieve high dosage, and adding other effective conservative treatments. Stretching and muscle-strengthening exercises seem to be the most effective types of exercises for treating chronic low back pain. Future study should further assess specific exercise strategies.

Figure 4. **Mean rank of included exercise types on the basis of association with improved pain (*top*) and function (*bottom*) outcomes at earliest follow-up compared with no treatment or other conservative treatment.**



Lines indicate 95% credible intervals for exercise type ranks.

From Institute for Work & Health and University of Toronto, Toronto, Ontario, Canada, and Institute for Research in Extramural Medicine, VU University Medical Center, Amsterdam, the Netherlands.

Acknowledgments: The authors thank Drs. Bart Koes and Antti Malmivaara for their contribution to the data collection and participation in the summative analysis of this review; the Physiotherapy "Educational Influentials" from the Institute for Work & Health for their guidance with syntheses; and Victoria Pennick for her assistance with editing.

Grant Support: No external funding was obtained for this study. Dr. Hayden is funded by a postdoctoral fellowship award from the Canadian Institutes of Health Research and Canadian Chiropractic Research Foundation.

Potential Financial Conflicts of Interest: None disclosed.

Corresponding Author: Jill A. Hayden, DC, Institute for Work & Health, 481 University Avenue, Suite 800, 8th Floor, Toronto, Ontario M5G 2E9, Canada; e-mail, jhayden@iwh.on.ca.

Current author addresses are available at www.annals.org.

References

1. **Hayden JA, van Tulder MW, Malmivaara AV, Koes BW.** Meta-analysis: exercise therapy for nonspecific low back pain. Ann Intern Med. 2005;142:765-75.
2. **Nordin M, Campello M.** Physical therapy: exercises and the modalities: when, what, and why? Neurol Clin. 1999;17:75-89. [PMID: 9855672]
3. **Koes BW, Bouter LM, Beckerman H, van der Heijden GJ, Knipschild PG.** Physiotherapy exercises and back pain: a blinded review. BMJ. 1991;302:1572-6. [PMID: 1830233]
4. **van Tulder M, Furlan A, Bombardier C, Bouter L.** Updated method guidelines for systematic reviews in the cochrane collaboration back review group. Spine. 2003;28:1290-9. [PMID: 12811274]
5. **Salaffi F, Stancati A, Silvestri CA, Ciapetti A, Grassi W.** Minimal clinically important changes in chronic musculoskeletal pain intensity measured on a numerical rating scale. Eur J Pain. 2004;8:283-91. [PMID: 15207508]
6. **Bombardier C, Hayden J, Beaton DE.** Minimal clinically important difference. Low back pain: outcome measures. J Rheumatol. 2001;28:431-8. [PMID: 11246692]
7. **Deyo RA, Walsh NE, Martin DC, Schoenfeld LS, Ramamurthy S.** A controlled trial of transcutaneous electrical nerve stimulation (TENS) and exercise for chronic low back pain. N Engl J Med. 1990;322:1627-34. [PMID: 2140432]
8. **Cherkin DC, Deyo RA, Battié M, Street J, Barlow W.** A comparison of physical therapy, chiropractic manipulation, and provision of an educational booklet for the treatment of patients with low back pain. N Engl J Med. 1998; 339:1021-9. [PMID: 9761803]
9. **Ljunggren AE, Weber H, Kogstad O, Thom E, Kirkesola G.** Effect of exercise on sick leave due to low back pain. A randomized, comparative, long-term study. Spine. 1997;22:1610-6; discussion 1617. [PMID: 9253097]
10. **Hemmilä HM, Keinänen-Kiukaanniemi SM, Levoska S, Puska P.** Does folk medicine work? A randomized clinical trial on patients with prolonged back pain. Arch Phys Med Rehabil. 1997;78:571-7. [PMID: 9196462]
11. **Abenhaim L, Rossignol M, Valat JP, Nordin M, Avouac B, Blotman F, et al.** The role of activity in the therapeutic management of back pain. Report of the International Paris Task Force on Back Pain. Spine. 2000;25:1S-33S. [PMID: 10707404]
12. **Johannsen F, Remvig L, Kryger P, Beck P, Warming S, Lybeck K, et al.** Exercises for chronic low back pain: a clinical trial. J Orthop Sports Phys Ther. 1995;22:52-9. [PMID: 7581431]
13. **Kuukkanen TM, Mälkiä EA.** An experimental controlled study on postural sway and therapeutic exercise in subjects with low back pain. Clin Rehabil. 2000; 14:192-202. [PMID: 10763797]
14. **Petersen T, Kryger P, Ekdahl C, Olsen S, Jacobsen S.** The effect of McKenzie therapy as compared with that of intensive strengthening training for the treatment of patients with subacute or chronic low back pain: A randomized controlled trial. Spine. 2002;27:1702-9. [PMID: 12195058]
15. **Bendix AF, Bendix T, Ostenfeld S, Bush E, Andersen A.** Active treatment programs for patients with chronic low back pain: a prospective, randomized, observer-blinded study. Eur Spine J. 1995;4:148-52. [PMID: 7552649]
16. **Bendix T, Bendix A, Labriola M, Haestrup C, Ebbehøj N.** Functional restoration versus outpatient physical training in chronic low back pain: a randomized comparative study. Spine. 2000;25:2494-500. [PMID: 11013502]
17. **Hildebrandt VH, Proper KI, van den Berg R, Douwes M, van den Heuvel SG, van Buuren S.** [Cesar therapy is temporarily more effective in patients with chronic low back pain than the standard treatment by family practitioner: randomized, controlled and blinded clinical trial with 1 year follow-up]. Ned Tijdschr Geneeskd. 2000;144:2258-64. [PMID: 11109471]
18. **Soukup MG, Glomsröd B, Lönn JH, Bö K, Larsen S.** 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: 1585-91; discussion 1592. [PMID: 10457579]
19. **Gelman A, Carlin JB, Stern HS, Rubin DB.** Bayesian Data Analysis. 2nd ed. Boca Raton, FL: Chapman & Hall/CRC Pr; 2004.
20. **Spiegelhalter D, Abrams KR, Myles JP.** Bayesian Approaches to Clinical Trials and Health-Care Evaluation. Chichester, United Kingdom: J Wiley; 2004.
21. **Spiegelhalter D, Thomas A, Best N, Lunn D.** WinBUGS User Manual Version 1.4.1. London: Imperial College and Medical Research Council; 2003.
22. **Alexandre NM, de Moraes MA, Corrêa Filho HR, Jorge SA.** Evaluation of a program to reduce back pain in nursing personnel. Rev Saude Publica. 2001; 35:356-61. [PMID: 11600924]
23. **Aure OF, Nilsen JH, Vasseljen O.** Manual therapy and exercise therapy in patients with chronic low back pain: a randomized, controlled trial with 1-year follow-up. Spine. 2003;28:525-31; discussion 531-2. [PMID: 12642755]
24. **Bentsen H, Lindgärde F, Manthorpe R.** The effect of dynamic strength back exercise and/or a home training program in 57-year-old women with chronic low back pain. Results of a prospective randomized study with a 3-year follow-up period. Spine. 1997;22:1494-500. [PMID: 9231969]
25. **Bronfort G, Goldsmith CH, Nelson CF, Boline PD, Anderson AV.** Trunk exercise combined with spinal manipulative or NSAID therapy for chronic low back pain: a randomized, observer-blinded clinical trial. J Manipulative Physiol Ther. 1996;19:570-82. [PMID: 8976475]
26. **Buswell J.** Low back pain: a comparison of two treatment programmes. New Zealand Journal of Physiotherapy. 1982;10:13-7.
27. **Dalichau S, Scheele K.** [Effects of elastic lumbar belts on the effect of a muscle training program for patients with chronic back pain]. Z Orthop Ihre Grenzgeb. 2000;138:8-16. [PMID: 10730357]
28. **Descarreaux M, Normand MC, Laurencelle L, Dugas C.** Evaluation of a specific home exercise program for low back pain. J Manipulative Physiol Ther. 2002;25:497-503. [PMID: 12381971]
29. **Elnaggar IM, Nordin M, Sheikhzadeh A, Parnianpour M, Kahanovitz N.** Effects of spinal flexion and extension exercises on low-back pain and spinal mobility in chronic mechanical low-back pain patients. Spine. 1991;16:967-72. [PMID: 1835157]
30. **Frost H, Klaber Moffett JA, Moser JS, Fairbank JC.** Randomised controlled trial for evaluation of fitness programme for patients with chronic low back pain. BMJ. 1995;310:151-4. [PMID: 7833752]
31. **Hansen FR, Bendix T, Skov P, Jensen CV, Kristensen JH, Krohn L, et al.** Intensive, dynamic back-muscle exercises, conventional physiotherapy, or placebo-control treatment of low-back pain. A randomized, observer-blind trial. Spine. 1993;18:98-108. [PMID: 8434332]
32. **Kankaanpää M, Taimela S, Airaksinen O, Hänninen O.** The efficacy of active rehabilitation in chronic low back pain. Effect on pain intensity, self-experienced disability, and lumbar fatigability. Spine. 1999;24:1034-42. [PMID: 10332798]
33. **Kendall PH, Jenkins JM.** Exercises for backache: a double-blind controlled trial. Physiotherapy. 1968;54:154-7.
34. **Kuukkanen TM, Mälkiä EA.** An experimental controlled study on postural sway and therapeutic exercise in subjects with low back pain. Clin Rehabil. 2000; 14:192-202. [PMID: 10763797]
35. **Lidström A, Zachrisson M.** Physical therapy on low back pain and sciatica. An attempt at evaluation. Scand J Rehabil Med. 1970;2:37-42. [PMID: 4257208]

36. **Lie H, Frey S.** [Mobilizing or stabilizing exercise in degenerative disk disease in the lumbar region?]. Tidsskr Nor Laegeforen. 1999;119:2051-3. [PMID: 10394282]
37. **Manniche C, Hesselsøe G, Bentzen L, Christensen I, Lundberg E.** Clinical trial of intensive muscle training for chronic low back pain. Lancet. 1988;2: 1473-6. [PMID: 2904582]
38. **Mannion AF, Müntener M, Taimela S, Dvorak J.** A randomized clinical trial of three active therapies for chronic low back pain. Spine. 1999;24:2435-48. [PMID: 10626305]
39. **Moseley L.** Combined physiotherapy and education is efficacious for chronic low back pain. Aust J Physiother. 2002;48:297-302. [PMID: 12443524]
40. **Preyde M.** Effectiveness of massage therapy for subacute low-back pain: a randomized controlled trial. CMAJ. 2000;162:1815-20. [PMID: 10906914]
41. **Risch SV, Norvell NK, Pollock ML, Risch ED, Langer H, Fulton M, et al.** Lumbar strengthening in chronic low back pain patients. Physiologic and psychological benefits. Spine. 1993;18:232-8. [PMID: 8185727]
42. **Rittweger J, Just K, Kautzsch K, Reeg P, Felsenberg D.** Treatment of chronic lower back pain with lumbar extension and whole-body vibration exercise: a randomized controlled trial. Spine. 2002;27:1829-34. [PMID: 12221343]
43. **Torstensen TA, Ljunggren AE, Meen HD, Odland E, Mowinckel P, Geijerstam S.** Efficiency and costs of medical exercise therapy, conventional physiotherapy, and self-exercise in patients with chronic low back pain. A pragmatic, randomized, single-blinded, controlled trial with 1-year follow-up. Spine. 1998; 23:2616-24. [PMID: 9854761]
44. **Tritilanunt T, Wajanavisit W.** The efficacy of an aerobic exercise and health education program for treatment of chronic low back pain. J Med Assoc Thai. 2001;84 Suppl 2:S528-33. [PMID: 11853276]
45. **Turner JA, Clancy S, McQuade KJ, Cardenas DD.** Effectiveness of behavioral therapy for chronic low back pain: a component analysis. J Consult Clin Psychol. 1990;58:573-9. [PMID: 2147702]
46. **Zylbergold RS, Piper MC.** Lumbar disc disease: comparative analysis of physical therapy treatments. Arch Phys Med Rehabil. 1981;62:176-9. [PMID: 6453571]
47. **Calmels P, Jacob JF, Fayolle-Minon I, Charles C, Bouchet JP, Rimaud D, et al.** [Use of isokinetic techniques vs standard physiotherapy in patients with chronic low back pain. Preliminary results]. Ann Readapt Med Phys. 2004;47: 20-7. [PMID: 14967569]
48. **Frost H, Lamb SE, Doll HA, Carver PT, Stewart-Brown S.** Randomised controlled trial of physiotherapy compared with advice for low back pain. BMJ. 2004;329:708. [PMID: 15377573]
49. **Galantino ML, Bzdewka TM, Eissler-Russo JL, Holbrook ML, Mogck EP, Geigle P, et al.** The impact of modified Hatha yoga on chronic low back pain: a pilot study. Altern Ther Health Med. 2004;10:56-9. [PMID: 15055095]
50. **Gur A, Karakoc M, Cevik R, Nas K, Sarac AJ, Karakoc M.** Efficacy of low power laser therapy and exercise on pain and functions in chronic low back pain. Lasers Surg Med. 2003;32:233-8. [PMID: 12605431]
51. **Jousset N, Fanello S, Bontoux L, Dubus V, Billabert C, Vielle B, et al.** Effects of functional restoration versus 3 hours per week physical therapy: a randomized controlled study. Spine. 2004;29:487-93; discussion 494. [PMID: 15129059]
52. **Niemistö L, Lahtinen-Suopanki T, Rissanen P, Lindgren KA, Sarna S, Hurri H.** A randomized trial of combined manipulation, stabilizing exercises, and physician consultation compared to physician consultation alone for chronic low back pain. Spine. 2003;28:2185-91. [PMID: 14520029]
53. **Rasmussen-Barr E, Nilsson-Wikmar L, Arvidsson I.** Stabilizing training compared with manual treatment in sub-acute and chronic low-back pain. Man Ther. 2003;8:233-41. [PMID: 14559046]
54. **Yelland MJ, Glasziou PP, Bogduk N, Schluter PJ, McKernon M.** Prolotherapy injections, saline injections, and exercises for chronic low-back pain: a randomized trial. Spine. 2004;29:9-16; discussion 16. [PMID: 14699269]
55. **Yeung CK, Leung MC, Chow DH.** The use of electro-acupuncture in conjunction with exercise for the treatment of chronic low-back pain. J Altern Complement Med. 2003;9:479-90. [PMID: 14499023]
56. **Yozbatiran N, Yildirim Y, Parlak B.** Effects of fitness and aquafitness exercises on physical fitness in patients with chronic low back pain. The Pain Clinic. 2004;16:35-42.
57. **Berlin JA, Santanna J, Schmid CH, Szczech LA, Feldman HI.** Individual patient- versus group-level data meta-regressions for the investigation of treatment effect modifiers: ecological bias rears its ugly head. Stat Med. 2002;21:371-87. [PMID: 11813224]
58. **Hilde G, Bo K.** Effect of exercise in the treatment of chronic low back pain: a systematic review emphasising type and dose of exercise. Physical Therapy Reviews. 1998;3:107-17.
59. **Faas A.** Exercises: which ones are worth trying, for which patients, and when? Spine. 1996;21:2874-8; discussion 2878-9. [PMID: 9112711]
60. Philadelphia Panel evidence-based clinical practice guidelines on selected rehabilitation interventions for low back pain. Phys Ther. 2001;81:1641-74. [PMID: 11589642]

Current Author Addresses: Dr. Hayden: Institute for Work & Health, 481 University Avenue, Suite 800, Toronto, Ontario M5G 2E9, Canada.
Dr. van Tulder: Institute for Research in Extramural Medicine, VU University Medical Center, van der Boechorststraat 7, 1081 BT Amsterdam, the Netherlands.
Dr. Tomlinson: Division of Clinical Decision Making & Health Care Research, Toronto General Research Institute, TGH, 200 Elizabeth Street, Toronto, Ontario M5G 2C4, Canada.