Motor Control Exercises Reduces Pain and Disability in Chronic and Recurrent Low Back Pain

A Meta-Analysis

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Study Design. Meta-analysis of randomized, controlled trials.
Objective. To determine the short-term, intermediate, and long-term effectiveness of MCE, with regard to pain and disability, in patients with chronic and recurrent low-back pain.

Summary of Background Data. Previous meta-analyses have shown no difference between the effects of MCE and general exercise in the treatment of low back pain. Several high quality studies on this topic have been published lately, warranting a new meta-analysis.

Methods. We searched electronic databases up to October 2011 for randomized controlled trials clearly distinguishing MCE from other treatments. We extracted pain and disability outcomes and converted them to a 0 to 100 scale. We used the RevMan5 (Nordic Cochrane Centre, Copenhagen, Denmark) software to perform pooled analyses to determine the weighted mean differences (WMDs) between MCE and 5 different control interventions.

Results. Sixteen studies were included. The pooled results favored MCE compared with general exercise with regard to disability during all time periods (improvement in WMDs ranged from −4.65 to −4.86), and with regard to pain in the short and intermediate term (WMDs were −7.80 and −6.06, respectively). Compared with spinal manual therapy, MCE was superior with regard to disability during all time periods (the WMDs ranged between −5.27 and −6.12), but not with regard to pain. Furthermore, MCE was superior to minimal intervention during all time periods with regard to both pain (the WMDs ranged between −10.18 and −13.32) and disability (the WMDs ranged between −5.62 and −9.00).

Conclusion. In patients with chronic and recurrent low back pain, MCE seem to be superior to several other treatments. More studies are, however, needed to investigate what subgroups of patients experiencing LBP respond best to MCE.

Key words: exercise therapy, low back pain, motor control, multifidus, rehabilitation, stability exercise, transversus. Spine 2013;38:E350–E358

Low back pain (LBP) is one of the most common pain complaints, with a lifetime prevalence of between 60% and 80%.1 Despite this, the etiology of LBP remains largely unknown and the majority of cases do not receive a specific diagnosis, giving rise to the term “nonspecific LBP”1,2. One proposed mechanism in the development of LBP is that spinal instability causes injury to structures with embedded mechanoreceptors.3,4 Panjabi1,5 hypothesized that spinal stability depends on 3 systems: the passive articular system, an active muscular system, and a neural control system. Bergmark6 divided the muscular system into a local system, which fine controls intervertebral motion, and a global system, which generates spinal motion. Muscles that have been argued to play a major role in spinal stability are primarily the transversus abdominis (TrA) and the multifidus, but also the pelvic floor and the diaphragm.6-10 Recent research has proposed that the activity of the TrA is associated with postural demand in standing.11 In individuals with LBP, the local musculature exhibits disturbed motor control patterns and changed physiological properties.7,10-17 Motor control exercises (MCE) have been devised to correct these deficiencies and retrain optimal movement patterns and control of spinal motion and are currently being used by physical therapists worldwide in the treatment of LBP. Five systematic reviews on MCE in LBP have been published,18-22 2 of which carried out pooled analyses.18,21 Macedo et al18 searched the literature up to June 2008 and concluded that MCE is superior to minimal intervention, but not to spinal manual therapy or general exercise in subacute, chronic, and recurrent LBP. Since 2008, a number of high quality, randomized controlled trials (RCTs) have been published, warranting an updated pooled analysis. The objective of the present meta-analysis was to investigate the short-term, intermediate, and long-term effect of MCE
with regard to pain and disability in patients with chronic and recurrent LBP.

MATERIALS AND METHODS

Criteria for Inclusion
We included RCTs reported in English and available online, and including participants at least 16 years of age classified as having chronic or recurrent LBP. We also included studies containing some subacute patients if the average duration exceeded 6 months or if more than 80% of the participants had chronic LBP. In this study, “chronic” denotes a duration of more than 12 weeks and “recurrent LBP” is defined as pain recurring after a pain-free interval. “Acute” denotes a duration of 0 to 3 weeks and “subacute” is used to mean 4 to 12 weeks. The study design had to include at least one intervention arm with MCE, that is, with the intervention labeled as MCE, segmental stabilizing exercise, or specific stabilizing exercise. The intervention was also considered MCE if it included exercises described as “abdominal hollowing” or “abdominal draw-in” or if it was stated that the initial stage aimed to isolate isometric contraction of the TrA and/or the MF. Only RCTs with a clear contrast between MCE and other treatments were included in the study, as recommended by the Cochrane Back Review Group. For example; studies investigating a combination of MCE and spinal manual therapy had to include a control group treated with only spinal manual therapy. The follow-up period had to be at least 6 weeks, and outcome measures had to include pain and/or disability. Finally, the outcomes had to be reported on a continuous scale, giving either the mean change from baseline and corresponding standard deviation (SD) or data that allowed calculation of these values, such as quartiles or standard errors. We excluded studies whose participants had undergone back surgery during the year prior to the intervention start, or experienced rheumatoid arthritis, osteoporosis, fractures, malignancies, or any kind of systemic diseases or nonmechanical LBP, or were pregnant/experienced postnatal-related LBP.

Identification and Selection of Studies
A systematic search for relevant studies was performed up to October 2011 in the PubMed, EMBASE, PEDro, and CINAHL databases, as recommended by the Cochrane Back Review Group. The following search path was used: (low back pain) AND (segmental OR stabil* OR multifidus OR transversus OR core OR (motor control)). Limits: RTC, human trials, written in English.

Two reviewers examined the titles and selected relevant studies. The abstracts of the remaining studies were then reviewed and more studies were excluded. Finally, the remaining studies were investigated in full length and a final selection of studies was made. The second reviewer was blinded to the authors of the studies when making the selection.

Methodological Quality Assessment
The 10-point PEDro scale was used to determine the quality of the included studies to identify high-quality (≥6 points) and low-quality (<6 points) studies. All included studies had already been rated by raters of the PEDro database. The quality assessment was not used to exclude studies.

Data Extraction and Analysis
The included studies were sorted into the following categories:
1. MCE versus general exercise.
2. MCE versus spinal manual therapy.
3. MCE versus minimal intervention.
4. MCE versus multimodal physical therapy.
5. MCE as part of a multimodal intervention versus the other components of that intervention.

Three follow-up time periods were considered: a short-term: 6 weeks or more and less than 4 months; intermediate-term: 4 or more and less than 8 months; and long-term period: 8 months or more and less than 15 months. If one study reported outcomes at multiple time points within the same time period, the outcome closest to 3 months, 6 months, and 12 months was considered. General exercise constituted any exercise other than MCE. Similar categories have been used in previous reviews. “Minimal intervention” is defined here as no intervention, or as advice/education or placebo treatment.

Pain and disability scores were transformed to a common 0 to 100 point scale. The RevMan5 (Nordic Cochrane Centre, Copenhagen, Denmark) software was used to calculate the weighted mean difference (WMD) between the index and the control intervention, or as advice/education or placebo treatment. The follow-up period had to be at least 6 months, and outcome measures had to include pain and/or disability. Finally, the outcomes had to be reported on a continuous scale, giving either the mean change from baseline and corresponding standard deviation (SD) or data that allowed calculation of these values, such as quartiles or standard errors. We excluded studies whose participants had undergone back surgery during the year prior to the intervention start, or experienced rheumatoid arthritis, osteoporosis, fractures, malignancies, or any kind of systemic diseases or nonmechanical LBP, or were pregnant/experienced postnatal-related LBP.

RESULTS
The systematic search retrieved 117 studies from PubMed, 107 from EMBASE, 72 from PEDro, and 21 from www.spinejournal.com
CINAHL. After removing duplicative studies, a total of 184 studies remained. Of these, 117 were excluded on the basis of their title, 6 were not written in English, and 2 were not available online. We excluded another 43 studies after reviewing their abstracts or full text. Seventeen of these were excluded because they did not report relevant outcomes. Nine were excluded because the intervention did not constitute MCE. Seven were pilot studies or descriptions of study designs and not RCTs. The remaining studies were excluded for the following reasons: 3 studies did not provide a clear contrast, 3 studies included subjects without LBP, 2 studies included subjects with acute LBP, 1 study included subjects who had undergone surgery, and the follow-up period of one study was too short. The systematic search, therefore, resulted in a total of 16 included studies (Tables 1–5). The methodological quality of the included studies varied from 4 to 9 points on the PEDro scale, with an average of 6.4. Ten studies were of high quality and 6 were of low quality.

**Motor Control Exercise Versus General Exercise**

Seven studies compared effects of MCE to effects of general exercise.30–36 One of these provided comparisons with 2 different types of general exercise, sling exercise, and a combination of general strengthening and stretching. Consequently, 8 comparisons were included in this category (Table 1). The pooled results favored MCE with regard to pain in the short (WMD, −7.80; CI, −10.95 to −4.65) and intermediate term (WMD, −6.06; CI, −10.94 to −1.18) and also with regard to disability in the short (WMD, −4.65; CI, −6.20 to −3.11),

<table>
<thead>
<tr>
<th>Study</th>
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<th>Participants</th>
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<tbody>
<tr>
<td>Unsgaard-Tondel et al30</td>
<td>7/10, high quality</td>
<td>N = 109. Male and female, 19–60 (mean, 40.1) yr. LBP ≥3 mo.</td>
<td>(1) MCE. (2) GE: sling exercise. One session/wk for 8 wk.</td>
<td>Pain (NRS), 8 wk and 1 yr; disability (ODI), 8 wk</td>
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<td>Unsgaard-Tondel et al30</td>
<td>7/10, high quality</td>
<td>N = 109. Male and female 19–60 (mean, 40.1) yr. LBP ≥3 mo.</td>
<td>(1) MCE. (2) GE: trunk strengthening and stretching. 1 session/wk for 8 wk.</td>
<td>Pain (NRS), 8 wk and 1 yr; disability (ODI), 8 wk</td>
</tr>
<tr>
<td>Franca et al31</td>
<td>7/10, high quality</td>
<td>N = 30. Male and female, mean, 41.9 yr. LBP ≥3 mo.</td>
<td>(1) MCE. (2) GE: trunk strengthening. 12 sessions during 6 wk. Home exercise was discouraged.</td>
<td>Pain (VAS, MPQ); disability (ODI), 6 wk</td>
</tr>
<tr>
<td>Rasmussen-Barr et al32</td>
<td>7/10, high quality</td>
<td>N = 71. Male and female, 18–60 (mean, 38.5) yr. Recurrent LBP (&gt;8 wk), average duration, 10 yr.</td>
<td>(1) MCE. 1 session with PT every week for 8 wk, daily home training. (2) Instruction to take 30-min walks daily, general home exercises. 8 wk, meeting the PT 2 times (wk 1 and 8).</td>
<td>Disability (ODI); pain (VAS), 8 wk; 6, 12, and 36 mo</td>
</tr>
<tr>
<td>Akbari et al33</td>
<td>5/10 low quality</td>
<td>N = 49. 18–80 (mean, 39.8) yr. LBP ≥3 mo. Suitable for MCE (unable to contract TrAMF correctly).</td>
<td>(1) MCE. 2. GE: trunk strengthening. Both groups performed 16 sessions during 8 wk.</td>
<td>Pain (VAS); disability (BPS), 8 wk</td>
</tr>
<tr>
<td>Critchley et al34</td>
<td>7/10, high quality</td>
<td>N = 212. Male and female, ≥18 (mean, 44) yr. LBP ≥12 wk.</td>
<td>(1) MCE, individual PT followed by group exercises. Max 8 sessions, 90 min/session. (2) GE (strength and cardiovascular), stretching, education. Max 8 sessions, 90 min/session.</td>
<td>Disability (RMDQ); pain (0–100), 6, 12, and 18 mo</td>
</tr>
<tr>
<td>Ferreira et al35</td>
<td>8/10, high quality</td>
<td>N = 240. Male and female, 18–80 (mean, 53.6) yr. LBP ≥3 mo.</td>
<td>(1) MCE. (2) GE (strength and cardiovascular), stretching. Up to 12 sessions during 8 wk. Daily home exercise encouraged.</td>
<td>Pain (VAS); disability (RMDQ), 8 wk; 6, and 12 mo</td>
</tr>
<tr>
<td>Miller et al36</td>
<td>5/10, low quality</td>
<td>N = 30. Male and female, 19–87 (mean 49) yr. LBP ≥7 wk, mean duration 26 mo.</td>
<td>(1) MCE. (2) McKenzie (with SMT for some patients) during 6 wk, schedule determined by PT and patient. Home exercises prescribed.</td>
<td>Pain (SF-MPQ); disability (FSQ), 6 wk</td>
</tr>
</tbody>
</table>

BPS indicates back performance scale; FSQ, functional status questionnaire; GE, general exercise; LBP, low back pain; MCE, motor control exercise; mODI, modified Oswestry disability index; MPQ, McGill pain questionnaire; NRS, numerical rating scale; ODI, Oswestry low back pain disability questionnaire; PT, physiotherapist or physiotherapy; RMDQ, Roland-Morris disability questionnaire; SF-MPQ, short-form McGill pain questionnaire; SMT, spinal manual therapy; VAS, visual analogue scale; TrA, transversus abdominis; MF, multifidus.

Min denotes minimum; max, maximum.
intermediate (WMD, −4.86; CI, −8.59 to −1.13), and long term (WMD, −4.72; CI, −8.81 to −0.63) (Figure 1).

**Motor Control Exercise Versus Spinal Manual Therapy**

In this category, the pooled analysis included 3 studies (Table 2). Compared with spinal manual therapy, MCE was superior with regard to disability in the short (WMD, −6.12; CI, −11.94 to −0.30), intermediate (WMD, −5.27; CI, −9.52 to −1.01), and long term (WMD, −5.76; CI, −9.21 to −2.32). No significant differences were, however, found with regard to pain (Figure 2).

**Motor Control Exercise Versus Minimal Intervention**

Two studies compared MCE with minimal intervention concerning pain. The pooled results favored MCE with regard to the short (WMD, −12.48; CI, −19.04 to −5.93), intermediate (WMD, −10.18; CI, −16.64 to −3.72), and long term (WMD, −13.32; CI, −19.75 to −6.90). Three studies compared MCE with minimal intervention concerning disability (Table 3). The pooled results favored MCE in the short (WMD, −9.00; CI, −15.28 to −2.73), intermediate (WMD, −6.52; CI, −10.46 to −0.77), and long term (WMD, −6.64; CI, −11.72 to −1.57) (Figure 3).

**Motor Control Exercise Versus Multimodal Physical Therapy**

Four studies compared MCE with multimodal physical therapy (Table 4), but it was only possible to carry out a pooled analysis in the intermediate term because of the lack of reported short- and long-term outcomes. The results favored MCE with regard to pain (WMD, −14.20; CI, −21.23 to −7.16) and disability (WMD, −12.98; CI, −19.49 to −6.47) (Figure 4). A single study favored MCE in the short term with regard to pain and disability, whereas no significant long-term difference was reported in another single study.

**Motor Control Exercise as Part of a Multimodal Intervention Versus the Other Components of that Intervention**

A pooled analysis could not be carried out in this category, because the 2 included studies reported outcomes at different time points (Table 5). A single study favored general trunk strengthening compared with a combination of MCE and general trunk strengthening with regard to disability in the short term (Figure 5). No other significant differences were reported.
TABLE 4. Trials Comparing Motor Control Exercise With Multimodal Physical Therapy

<table>
<thead>
<tr>
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<tr>
<td>Kumar et al(^4)</td>
<td>5/10, low quality</td>
<td>N = 141. Male and female, 20–40 (mean, 35.08) yr. Subacute and chronic LBP, mean duration 33.65 mo.</td>
<td>(1) MCE. (2) Ultrasound, electrotherapy, lumbar strengthening. 20 sessions, then follow-up for 180 d.</td>
<td>Pain (VAS), 180 d</td>
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<tr>
<td>Kumar et al(^5)</td>
<td>7/10, high quality</td>
<td>N = 102. Male, 20–40 (mean, 34.06) yr. Subacute and chronic LBP, mean duration 25.37 mo.</td>
<td>(1) MCE. (2) Ultrasound, electrotherapy, lumbar strengthening. 20 sessions, then follow-up for 180 d.</td>
<td>Pain (VAS), 180 d</td>
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<td>Critchley et al(^6)</td>
<td>7/10, high quality</td>
<td>N = 212. Male and female, ≥18 (mean, 44) yr. LBP ≥12 wk.</td>
<td>(1) MCE, individual PT followed by group exercises. Max 8 sessions, 90 min/session. (2) Usual outpatient PT, passive PT &amp; GE. Max 12 sessions, 30 min/session.</td>
<td>Disability (RMDQ); pain (0–100), 6, 12, and 18 mo</td>
</tr>
<tr>
<td>O’Sullivan et al(^7)</td>
<td>7/10, high quality</td>
<td>N = 44. Male and female, 16–49 (mean, 31) yr. Recurrent LBP, current episode ≥3 mo. Spondylolisthesis/spondylolysisis.</td>
<td>(1) MCE. 10-week treatment, directed by PT on a weekly basis. Daily home exercise. (2) Control. 10-week treatment directed by the patient’s medical practitioner. Max 2 PT and GE.</td>
<td>Pain (SF-MPQ); disability (ODI), 3, 6, and 30 mo</td>
</tr>
</tbody>
</table>

GE indicates general exercise; LBP, low back pain; MCE, motor control exercise; ODI, Oswestry low back pain disability questionnaire; PT, physiotherapist or physiotherapy; RMDQ, Roland-Morris disability questionnaire; SF-MPQ, short-form McGill pain questionnaire; VAS, visual analogue scale.

DISCUSSION

The objective of the present meta-analysis was to establish the effect of MCE with regard to pain and disability in patients with chronic and recurrent LBP. The pooled results favored MCE compared with general exercise with regard to disability during all time periods. MCE was also superior to spinal manual therapy with regard to disability during all time periods but not with regard to pain. Compared with minimal intervention, MCE was superior with regard to both pain and disability during all time periods.

In contrast to these results, a previous, pooled analysis by Macedo et al\(^8\) reports no significant difference between MCE and general exercise, with the exception of disability in the short term. The results of the present study contrast with the opinion that any effects of MCE are merely due to the general effects of physical exercise.\(^9\) The differences between the present analysis and that by Macedo et al\(^8\) may be due to our inclusion of 4 recent studies.\(^10\)–\(^13\) The difference in results could however also be due to the application of stricter inclusion criteria in the current study, as recommended by the Cochrane Back Review Group.\(^14\) Two studies\(^15,16\) included by Macedo et al\(^8\) were excluded from the present meta-analysis because they did not provide a clear contrast for MCE.

The results presented in this meta-analysis suggest that MCE is superior to spinal manual therapy with regard to disability during all time periods, but not with regard to pain. In contrast, Macedo et al\(^8\) found only a significant difference in the intermediate term with regard to both disability and pain. These differences may be due to the fact that Macedo et al\(^8\) included a study,\(^17\) which in the present study was included in the category “MCE versus multimodal physical therapy.”

The present study reveals that MCE is more effective than minimal intervention in reducing both pain and disability.

TABLE 5. Trials Comparing Motor Control Exercise as Part of Multimodal Treatment With the Other Components of That Treatment

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Koumantakis et al(^8)</td>
<td>7/10, high quality</td>
<td>N = 55. Male and female. Mean age, 37.3 yr. Recurrent LBP, current episode ≥6 wk.</td>
<td>(1) MCE + GE. (2) GE: trunk strengthening. Twice per week for 8 wk.</td>
<td>Pain (SF-MPQ, VAS); disability (RMDQ), 3 mo</td>
</tr>
<tr>
<td>Cairns et al(^9)</td>
<td>7/10, high quality</td>
<td>N = 97. Male and female, 18–60 (mean, 38.7) yr. Recurrent LBP, average duration of current episode 8.7 mo.</td>
<td>(1) MCE. (2) Conventional PT. Both groups received passive PT and GE. Maximum of 12 sessions during 12 wk.</td>
<td>Disability (RMDQ); pain (SF-MPQ, NRS), 12 mo</td>
</tr>
</tbody>
</table>

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during the short, medium, and long term. This result concurs with the strong evidence for the effectiveness of exercise therapy in the treatment of chronic LBP. 

Due to a shortage of RCTs, no conclusion could be drawn on the effectiveness of MCE compared with multimodal physical therapy. There was also a lack of RCTs studying MCE as part of a multimodal treatment.

The quality of the included studies ranged from 4 to 9 on the PEDro scale. The average score of the 16 included studies was 6.4, that is, they were generally of high quality. It therefore seems unlikely that the validity of the results would be affected by poor study quality. The included studies exhibited heterogeneity in the population, as well as in LBP diagnosis and the MCE protocols with regard to parameters such as the length of intervention, methods used for feedback, etc.

This makes it harder to state how the results relate to the individual patient and any specific MCE protocol.

One methodological shortcoming of the current study was that several studies did not report the change from baseline SD, forcing us to impute this measure. In future studies, outcomes should preferably be reported as the mean change from baseline and the change from baseline SD. The conservative approach taken in this study, in the choice of the correlation coefficient, may have resulted in an underestimation of the statistical significance of the treatment effect.

Despite this, during the short, medium, and long term. This result concurs with the strong evidence for the effectiveness of exercise therapy in the treatment of chronic LBP. 

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should focus on associations between physical changes of the deep abdominals and improvement in pain and disability. So far, only one study has reported a moderate correlation.

approach, significant differences were found. These statistical differences do, however, not automatically imply clinical significance.

Studies without a clear contrast for MCE were excluded. Consequently, the pooled treatment effects presented are suggested to represent the effect of MCE only, uncontaminated by the effects of other treatments. To provide a clear contrast, future studies should ideally keep to a strict comparison between an MCE group and a control group receiving a single treatment. The effect of an exercise intervention, in this case MCE, may of course always be affected by other factors, such as the patient’s beliefs and expectation, the training of the physiotherapist, and placebo effects. Compared with other exercises, MCE are more body specific and performed with greater awareness and control. MCE may, therefore, have a greater effect on self-efficacy, a psychosocial factor proposed to be important in the rehabilitation of musculoskeletal disorders. To establish whether MCE are solely responsible for changes in pain and disability, future studies should focus on associations between physical changes of the deep abdominals and improvement in pain and disability. So far, only one study has reported a moderate correlation.

Figure 3. Motor control exercise versus minimal intervention. The forest plot shows mean difference between interventions (gray squares) and 95% confidence interval (95% CI) of individual trials, and pooled, weighted mean difference and 95% CI (black diamond) of all trials. All outcomes have been transformed to a common 0 to 100 scale.

Figure 4. Motor control exercise versus multimodal physical therapy. The forest plot shows mean difference (gray squares) and 95% confidence interval (95% CI) of individual trials, and pooled, weighted mean difference and 95% CI (black diamond) of all trials. All outcomes have been transformed to a common 0 to 100 scale.

Figure 5. Motor control exercise as part of multimodal treatment versus the other components of that treatment. The forest plot shows mean difference (gray squares) and 95% confidence interval of individual trials. All outcomes have been transformed to a common 0 to 100 scale.
One area of high priority in future research is the development of clinical methods to assess deficits in motor control. Such methods would allow subclassification of patients and the identification of those in need of MCE. This was recently suggested by Ferreira et al., who report that treatment effects of MCE are greater in those with poorer ability to activate TrA, implying one subgroup of patients experiencing LBP. It has been debated whether MCE should focus on isolated contraction of local musculature or if exercises should aim at engaging all abdominal and back extensor musculature to ensure spinal stability and robustness. Recent research suggests that there is an increased activation of the deep abdominals in functional and loaded postures. It is to date not known if the effect of MCE on pain and physical impairment in LBP is due to the isolated activation of the local musculature or subsequent stages of the intervention involving loaded postures engaging all trunk muscles. Isolated contraction of the local musculature does however seem to be necessary to restore disturbed activation patterns of the local musculature in the LBP population. Further research is needed to explore the underlying mechanisms to clarify the impact of these exercises on pain and functional limitations.

In conclusion, the results of this pooled analysis suggest that in patients with chronic or recurring LBP, MCE is superior to general exercise, manual therapy, and minimal intervention with regard to disability and pain. More studies are, however, needed to investigate what subgroups of patients experiencing LBP respond best to MCE.

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**Key Points**

- This meta-analysis includes randomized controlled studies of motor-control exercises until 2011.
- MCE is superior to general exercise in the treatment of chronic and recurrent low back pain with regard to pain and disability.
- MCE is superior to spinal manual therapy with regard to disability, but not with regard to pain.
- MCE is superior to minimal intervention with regard to pain and disability.

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