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Review article

Effectiveness of movement control exercise on patients with non-specific low back pain and movement control impairment: A systematic review and meta-analysis

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ABSTRACT

Background: Patients with low back pain (LBP) and movement control impairment (MVCI) show altered spinal movement patterns. Treatment that aims to change movement behaviour could benefit these patients.
Objective: To assess the effectiveness of movement control exercise (MVCE) in terms of clinically relevant measures (disability and pain) on patients with NSLBP.
Methods: A systematic review and meta-analysis were conducted. CINAHL, MEDLINE, PUBMED and PEDro databases were searched for RCT's evaluating MVCE treatment in patients with NSLBP from review inception to April 2017. Authors were contacted to obtain missing data and outcomes. PEDro was used to assess methodological quality of the studies and the GRADE approach was used to assess the overall quality of evidence Data were combined using a random effects meta-analysis and reported as standardized mean differences (SMD).
Results: Eleven eligible RCT's including a total of 781 patients were found. Results show 'very low to moderate quality' evidence of a positive effect of MVCE on disability, both at the end of treatment and after 12 months (SMD -0.38 95%CI -0.68, −0.09 respectively 0.37 95%CI -0.61,-0.04). Pain intensity was significantly reduced after MVCE at the end of treatment (SMD -0.39 95%CI -0.69, −0.04), but not after 12 months (SMD -0.27, 95%CI -0.62, 0.09).
Conclusions: MVCE intervention for people with NSLBP and MVCI appears to be more effective in improving disability compared to other interventions, both over the short and long term. Pain was reduced only in the short term. An important factor is the initial identification of patients with MVCI.
Registration of the study: The study protocol registration number is CRD42016036662 on PROSPERO.

1. Introduction

Low back pain (LBP) is a common condition that affects most people at some point in their lives, with up to an 84% lifetime prevalence (Airaksinen et al., 2006). The prevalence depends on factors such as sex, age, educational level and occupation (Delitto et al., 2012). It results in significant health and socioeconomic problems, being associated with work absenteeism, disability and high costs, both for patients and society (Saragiotto et al., 2016b). From 85% to 95% of affected LBP patients no pathoanatomic cause can be identified (Hoy et al., 2010) and they are designated as suffering from non-specific low back pain (NSLBP).

One proposed mechanism driving NSLBP is movement control impairment (MVCI). The latter is defined as an alteration of the spinal alignment and movement pattern in a specific direction (Sahrmann, 2002; Harris-Hayes and Van Dillen, 2009). It has been suggested that it is a clinical feature of patients with NSLBP (O'Sullivan, 2005). This impairment occurs secondary to the presence of pain and can be due to abnormal tissue loading, lack of proprioceptive awareness and, possibly, the lack of a withdrawal reflex motor response (O'Sullivan, 2005). Other circumstances, such as psychological, social and neurophysiological factors, could contribute to reinforce this disorder (O'Sullivan, 2005).

Abbreviations: MVCE, Movement control exercises; MVCI, Movement control impairment; LBP, Low back pain; NSLBP, Non-specific low back pain; SD, Standard deviation; SMD, Standardized mean differences

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Patients exhibiting MVCI demonstrate clinical features that can be screened with the aid of various clinical tests, e.g. the movement control test battery, based on descriptions by Sahrmann (2002), Van Dillen et al. (Van Dillen et al., 2009) and by Luomajoki et al., 2007, 2008.

Based on this principle, treatment aimed at restoring movement control, correcting movement patterns and avoiding pain-provoking postures could benefit patients with MVCI. In this review, such intervention is called 'movement control exercise' (MVCE).

The movement control approach is different to that of motor control exercises, where the intervention involves training isolated deep trunk muscles and integrating the activation of these muscles into more complex static, dynamic and functional tasks. The focus of the motor control exercises is more on function and performance of individual muscles, such as multifidi and transversus abdominis. Reviews of this approach have already been published (Macedo et al., 2016; Saragiotto et al., 2016b). The MVCE used in our review is differentiated by its aim to change movement behaviour, through a combination of physical and cognitive learning processes (O'Sullivan, 2005), rather than just strengthening a muscle group.

There have been randomized control trials (RCT) in the past comparing MVCE with other interventions in patients with NSLBP and MVCI. These studies showed variable results for both disability and pain intensity. A systematic review and meta-analyses of the literature had not previously been conducted on this topic. The aim of this systematic review and meta-analysis was to determine the effectiveness of MVCE compared to alternative interventions in terms of clinically relevant measures, such as disability and pain intensity.

2. Methods

This systematic review process followed the guidelines of the Centre for Reviews and Disseminations (Centre for Reviews and Dissemination, 2009) and the Cochrane Handbook for Systematic Reviews of Interventions (Higgins and Green, 2011). Reporting of the systematic review and meta-analysis was in accordance with the PRISMA statement for reporting systematic reviews and meta-analyses of randomized control trials (Moher et al., 2009). The PRISMA checklist can be found in Appendix S1. The GRADE approach was used to rate the quality of evidence. The study protocol registration number is CRD42016036662 on PROSPERO.

2.1. Eligibility criteria

Randomized controlled trials comparing MVCE with other active interventions were included in order that the specific effects of the type of exercises and patient education could be compared. No publication date or publication status restrictions were imposed.

Participants selected were adults with NSLBP. No restrictions in terms of pain duration were applied.

The interventions included were trials evaluating MVCE that were directed at changing the subject's posture, movement and lifestyle behaviours with a view to normalizing the impairment (O'Sullivan, 2005; Sahrmann, 2002; Luomajoki, 2010; Luomajoki et al., 2010). There were no restrictions on duration, frequency or intensity of the intervention. Other adjuvant treatments were accepted, but MVCE had to be the main content of the therapy program (more than 50%). Studies that used only trunk stabilization exercises or a motor control approach in the intervention group, such as training of the abdominal or multifidus muscles, were excluded.

Outcome measures used were disability and pain intensity. For a study to be eligible, it had to include at least one disability assessment or one pain assessment. It was also essential that the assessment was made using a validated method of disability measurement, such as the Patient-Specific Functional Scale (PSFS), Oswestry Disability Index (ODI) or Roland Morris Disability Questionnaire (RMDQ). A validated method was also a requirement for the assessment of pain intensity, e.g. the Visual Analog Scale (VAS), Numeric Pain Rating Scale (NPRS), Graded Chronic Pain Scale (GCPS) or McGill Pain Questionnaire (McGill NPI).

2.2. Search method for identification of studies

The CINAHL, MEDLINE, PUBMED and PEDro databases were searched from review inception to April 2017. The search strategy used was as recommended by the Cochrane Back Review Group (Furlan et al., 2015c). The search terms used were: LBP, movement control, motor control, randomized control trial (see supporting information, Appendix S2 for detailed search strategy). Additional key author searches were performed. A search for previous systematic reviews and meta-analyses on this subject was made, but none were found. The search strategy was independently performed by two reviewers and verified by a third.

To minimize publication bias, searches were made on relevant databases for grey literature, such as the DART-Europe E-theses Portal, Open Grey, British Library EThOS, the International Clinical Trials Registry Platform (ICTRP) from the WHO and Google Scholar.

2.3. Study selection

All articles relating to abstracts of potential relevance identified in the initial screening were obtained and independently assessed for eligibility by two reviewers and verified by a third, based on the defined inclusion criteria. Any study published in a language other than English or German was excluded to ensure correct interpretation.

2.4. Data extraction

Data was extracted on: author, year of study and country; indication, MVCI assessment and number of participants; content of intervention group and control group, study setting, frequency, duration and intensity of intervention group; follow-up duration, adherence to follow-up, losses at follow-up and outcomes. For missing data, the primary author of the study was contacted when necessary.

2.5. Data synthesis

For outcomes reported as continuous variables, means and standard deviations were extracted. When unreported, standard deviations were estimated from variance measures, according to the Cochrane Collaboration (Higgins and Green, 2011). Where studies used different assessment questionnaires for disability or measurement scales for pain, data were treated as being comparable. Where outcomes for the same domain were reported using different measurement methods, appropriate conversions were applied (Higgins and Green, 2011). All disability and pain scores were converted to a 0–100 scale (Higgins and Green, 2011).

2.6. Quality of methodology and level of evidence assessment

Firstly, the individual studies were rated for their methodological quality using the PEDro scale from The Physiotherapy Evidence Database (Sherrington et al., 2010; Physiotherapy Evidence Database). All individual papers were rated independently by two reviewers and verified by a third. For the outcomes of the meta-analysis, the quality of the evidence was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach (Ryan and Hill, 2016; Guyatt et al., 2008) as recommended by the Updated Method Guideline for Systematic Reviews in the Cochrane Back and Neck Group (Furlan et al., 2015b). The aim of the GRADE approach is to assess the overall quality of evidence. Following the GRADE guidelines (Ryan and Hill, 2016) the quality of evidence was categorized as follows:

- **High**: We are very confident that the true effect lies close to that of the estimate of the effect
- **Moderate**: We are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
- **Low**: Our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect
- **Very low**: We have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of the effect

For each outcome, we graded the evidence on the following domains:

1. **Study design**: In this study we only included randomized, controlled trials
2. **Risk of bias**: Two authors independently assessed the risk of bias concerning the PEDro Scale of the involved studies. No risk of bias was detected if the involved studies had a PEDro score of at least five points. If two or more studies had a PEDro score less than five the evidence will be downgraded by one point.
3. **Inconsistency**: Inconsistency refers to a heterogeneity due to any kind of variation across studies (Ryan and Hill, 2016). Inconsistency was evaluated considering I^2 for each outcome. The quality of evidence was not downgraded if the heterogeneity resulted as low ($I^2 < 40\%$). The quality of evidence was downgraded by one point when the heterogeneity or variability in results was considerable ($I^2 > 80\%$) (Chaparro et al., 2013; Ryan and Hill, 2016). The quality of evidence was downgraded by two points if the heterogeneity was considerable and there was inconsistency arising from populations or interventions.
4. **Indirectness**: We assessed how well the evidence included in the review answered the review question regarding the population, intervention, comparator or outcome. The quality of evidence was downgraded by one point if indirectness was detected in one area and by two points if there was indirectness in two or more areas.
5. **Imprecision**: Imprecision was considered for either of the following reasons
   (1) When the total population size was < 300
   (2) When 95% CI included the 0-Hypothesis and therefore the estimated effect was little or absent.

The quality of the evidence was downgraded by one point when there was imprecision due to (1) or (2) or we downgraded the quality of the evidence by two points when there was imprecision due to (1) and (2).

6. **Publication Bias**: To minimize publication bias an additional grey literature research was done. Therefore, the authors assumed that publication bias is undetected and did not downgrade the quality of evidence.
7. **Magnitude of the effect**: The authors did not assess this in this study
8. **Dose Response gradient**: The authors did not assess this in this study
9. **Influence of all plausible residual confounding**: The authors did not assess this in this study

The outcomes assessed were: comparison of the intervention group and control group for pain and disability, both after three months and 12 months. Furthermore, the outcomes were separated into studies that restricted their sample to patients with MVCI before randomization and those that did not. Two authors assessed the GRADE and were verified by a third person.

2.7. Data analysis

The analyses, defined a priori, were: MVCE intervention compared to another type of intervention. It was decided to analyse the findings of the selected studies using a qualitative synthesis approach, according to the Cochrane Collaboration (Higgins and Green, 2011), followed by a quantitative synthesis with a meta-analysis. When scales with opposing directions were included in the same analysis, the scales were harmonised. Scales where a higher score indicated a better outcome were inverted for the meta-analysis (Borenstein et al., 2009).

Subgrouping was based on patient selection and control intervention in the meta-analysis. The outcomes were compared between those studies restricting their samples to patients with MVCI, determined using a classification system for MVCI (O'Sullivan, 2005; Delitto et al., 1995; Mckenzie and May 2003; Petersen et al., 2003; Sahrmann, 2002; Luomajoki et al., 2007), against studies that did not restrict and generally included patients with NSLBP. Furthermore the outcomes were compared between those studies that compared MVCE to active interventions against studies with a non-intervention control group.

The combined effects were determined using a random effects model, to allow for the fact that the true effect could vary between studies (Borenstein et al., 2010). The mean values and standard deviations were compared between the groups at the end of treatment and after a 12-month follow-up. These were either extracted from the published results, according to Higgins and Green (2011), or requested from the corresponding authors. The total effect was estimated by means of the standardized mean difference (SMD) at 95% confidence intervals, since the selected studies measured pain and function on different scales. SMDs of 0.2, 0.5 and 0.8 indicate small, moderate and large effects, respectively (Higgins and Green, 2011). Heterogeneity was analysed using the Q, T^2, and I^2 tests. Q and its corresponding p-value (level of significance $p < 0.05$) assess the null-hypothesis that all studies share a common effect, T^2 measures the variance of the true effects, and I^2 the proportion of the observed dispersion between studies that is real (Borenstein et al., 2009). I^2 values of 25%, 50% and 75% indicate low, moderate and high proportion of real observed dispersion, respectively (Higgins et al., 2003). Analyses were performed in Review Manager (Version 5.3. Copenhagen: the Nordic Cochrane Centre, the Cochrane Collaboration, 2014).

3. Results

3.1. Searches

A summary of the search results is presented in Fig. 1. The literature search identified 161 papers. Following a review of the titles, abstracts and contents, eleven studies were found to be eligible and included in the qualitative and quantitative analyses.

3.2. Characteristics of the selected studies

The characteristics of the eleven selected studies are presented in Table 1. Individual studies ranged in size from 32 to 112 patients, with a total of 781 patients being included. Two studies characterized its population as having subacute NSLBP (Lehtola et al., 2016; Ng et al., 2015), whilst two other studies included subacute LBP, chronic LBP or pain for more than 6 weeks (Saner et al., 2015; Kent et al., 2015). Furthermore, five studies evaluated chronic LBP with a pain duration of three months or more (Aasa et al., 2015; Sheeran et al., 2013; Vibe Fersum et al., 2013; Suni et al., 2006; Salamat et al., 2017) and two trials included chronic LBP with a pain duration of 12 months or more (Henry et al., 2014; Jacobs et al., 2016). The studies followed different strategies regarding restriction of their samples. While a few of the

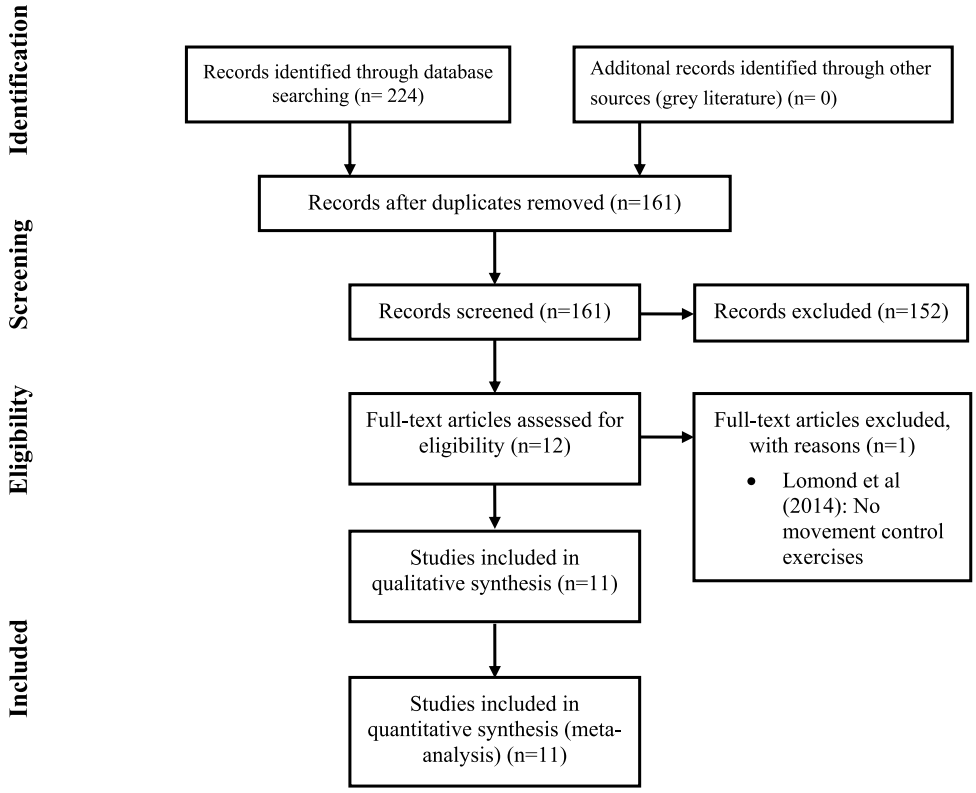

Fig. 1. PRISMA flow diagram depicting search strategy.

studies restricted their samples to patients with MVCI (Lehtola et al., 2016; Salamat et al., 2017; Saner et al., 2015; Sheeran et al., 2013; Vibe Fersum et al., 2013), other studies included all patients with non-specific LBP without restriction (Aasa et al., 2015; Henry et al., 2014; Jacobs et al., 2016; Kent et al., 2015; Suni et al., 2006). This fact may have affected the large heterogeneity between the studies.

3.3. Methodological quality

Risk of bias and quality of evidence for each trial was evaluated using the GRADE approach (Guyatt et al., 2008) and the PEDro Scale (Physiotherapy Evidence Database) was used to assess the methodological quality of the individual studies. These are summarized in Table 2 and 3 respectively.

The methodological quality assessment shows that all studies, except one, were of high quality (≥5/10 points on the PEDro scale) (Physiotherapy Evidence Database). GRADE assessment was conducted to assess the quality of evidence based on the subgrouping, according to sample restriction. The quality of evidence was very low to moderate for the studies that restricted their sample to participants with MVCI and very low for studies with no restricted sample.

3.4. Treatment effects

Figs. 2–5 show the meta-analysis of the effects between the MVCE group and the control group. The selected studies differed regarding their patient selection and their control intervention. Five studies (Lehtola et al., 2016; Salamat et al., 2017; Saner et al., 2015; Sheeran et al., 2013; Vibe Fersum et al., 2013) restricted their samples to patients with MVCI, while the other selected studies did not restrict (Aasa et al., 2015; Henry et al., 2014; Jacobs et al., 2016; Kent et al., 2015; Ng et al., 2015; Suni et al., 2006). Two studies had a non-intervention control group (Ng et al., 2015; Suni et al., 2006), while the others compared MVCE to active interventions (Aasa et al., 2015; Henry et al., 2014; Jacobs et al., 2016; Kent et al., 2015; Lehtola et al., 2016; Salamat et al., 2017; Saner et al., 2015; Sheeran et al., 2013; Vibe Fersum et al., 2013). Subgrouping was based on patient selection and control intervention in the meta-analysis.

Fig. 2–5 illustrate the SMD (95%CI) intervals of the individual studies, the total effect (95%CI), and the Q, T^2, and I^2 statistics for pain and disability at the end of treatment and at the 12-month follow-up.

3.5. Pain

Nine studies presented data on pain at the end of treatment and five on pain at the 12-month follow-up: using the numeric rating scale, visual analog scale and the graded chronic pain scale.

At end of treatment, three out of the nine studies showed a treatment effect in favour of MVCE (95%CI not crossing zero). Six studies revealed no effect in either direction. The total effect over all studies showed a small effect in favour of MVCE treatment (SMD -0.39, 95%CI -0.73 -0.04) (Fig. 2). Studies that restricted their sample to patients with MVCI showed a large effect in favour of MVCE (SMD -0.82, 95%CI -1.25 to −0.40). With regard to the SMD, the sole study with a non-intervention control group did not differ from the studies with an active control intervention.

After the 12-month follow-up, two of the five studies showed a treatment effect in favour of MVCE (95%CI not crossing zero). Three studies revealed no effect in either direction. The total effect over all studies showed no tendency in favour of movement control exercise or the control intervention (SMD -0.27, 95%CI -0.62 - 0.09) (Fig. 3). Studies that restricted their sample to patients with MVCI showed a small effect in favour of MVCE treatment (SMD -0.46, 95%CI -0.83 to −0.09) (Fig. 3).

3.6. Disability

Eleven studies presented data on disability at the end of treatment

Table 1
Characteristics of included studies.

Publication Location	Indication MCI assessment Number randomized (intervention:control)	Intervention group Study setting Frequency, duration and intensity Control group	Follow-up interval Outcomes Adherence to intervention Losses to follow-up
Aasa et al., 2015 Sweden	Pain and/or discomfort in lower back for 3 or more months Movement control test battery N = 70 (35:35)	Individual exercises aimed to normalize the dominating movement impairment and education regarding pain mechanism Physical therapy clinic for intervention group, sports centre for control group 12 individual treatment sessions in 8 weeks (weeks 1–4, 2 sessions per week, weeks 5–8, 1 session per week), 20–30 min per session, difficulty gradually increased in 3 phases (phase 1 each exercise 10 repetitions 2 or 3 times a day, phase 2 and 3, repeat exercises as often as possible) High-load lifting training with deadlift exercise (12 group treatment sessions in 8 weeks (weeks 1–4, 2 sessions per week, weeks 5–8, 1 session per week), 60 min per session) and education regarding pain mechanism	At 2 and 12 months PSFS, average pain over last 7 days with VAS, physical performance test battery including movement control test battery 25/28 completed program (71%) (10:7) not followed up
Henry et al., 2014 USA	Chronic LBP (≥12months) Movement control test battery N = 39 (23:16)	Education on positions or postures to control subject's symptoms, specific trunk movements and postures free of pain and functional activity modifications to change trunk movement and alignment patterns 4 different outpatient physical therapy clinics One treatment session per week, for 6 weeks, home exercises daily and keep an exercise log Stabilization protocol with motor control of deep trunk muscles, strengthening of flexor, extensor and oblique trunk muscles and patient education in an education booklet	At 7 weeks and 12 months Modified ODI, NPRS, GCPS, McGill NPI, fear-avoidance behaviour questionnaire, PSFS and SF-36 91% 23/16 completed program
Jacobs et al. 2016 USA	Chronic LBP (≥12months) Standard clinical exam. N = 68 (41:27)	Exercises to modify the subject's specific trunk movements and postures, functional-activity modifications to change subject's trunk movements and alignment patterns, education about specific lumbopelvic movement patterns and postures to avoid lumbar-tissue stress and also positions to control symptoms 6 different outpatient physical therapy clinics One treatment session per week, for 6 weeks, 1 h sessions plus prescribed home exercises Stabilization protocol for motor control of deep trunk muscles, coordination and strengthening of flexor, extensor and oblique trunk muscles and education booklet	At 7 weeks Modified ODI, NPRS and postural responses 41/27 completed program (100%) All subjects followed up
Lehtola et al., 2016 Finland	Sub-acute non-specific LBP Movement control test battery N = 70 (35:35)	Individual sensorimotor and cognitive learning through specific movement control exercises and manual therapy Private physiotherapy clinic 5 treatment sessions over three-month period, 45 min exercises and 10–15 min manual therapy, 3 sets of 15 repetitions for exercise, intensity increased over the 5 treatments, last session 30–40 min with 10–12 exercises, home exercises 3 times per week and other exercises daily General exercise targeted abdominal and paraspinal muscles without the involvement of specific deep muscle activation, frequency, duration and intensity same as intervention	At 3 and 12 months RMDQ, PSFS, ODI, movement control test, absence from work, need for other treatment, pain medication and patient satisfaction (86%) 30/31 completed program
Saner et al., 2015 Switzerland	Sub-acute or chronic (pain for more than 6 weeks) Movement control test battery N = 106 (52:54)	Individual active exercises addressing pain-provoking postures and control of impaired movements through specific movement control exercises and, if necessary, 10 min s of other physiotherapy applications 5 hospital outpatient departments and 8 private practices 2 treatment sessions per week over 9–12 weeks, 30 min per session, progression determined by the physiotherapist, 3 home exercises twice a week for up to one year General exercise for abdominals, erector spinae, gluteals, quadriceps and hamstrings, submaximal load, frequency, duration same as intervention	At end of programme, 6 and 12 months PSFS, RMDQ, GCPS 46/52 completed program (88%)

(*continued on next page*)

Table 1 (*continued*)

Publication Location	Indication MCI assessment Number randomized (intervention:control)	Intervention group Study setting Frequency, duration and intensity Control group	Follow-up interval Outcomes Adherence to intervention Losses to follow-up
Sheeran et al., 2013 United Kingdom	Non-specific chronic LBP (more than 12 weeks) Physical examination with functional movement and joint assessment N = 58 (29:29)	Discourage patient adopting end-range postures based on their movement impairment Individual phase consisting of 30 min session with 120 repetitions (60 sitting, 60 standing), each maintained 5 s interspersed with 5 s relax. 4 week home-based training phase consisting of 15 min posture training, 3 times a day with 60 repetitions (30 sitting, 30 standing) Posture training to facilitate patient to adopt mid-position regardless of their disorder type, home-based training had no focus on impairment type	At end of program (4 weeks) RMDQ, VAS and physical outcomes (thoracic and lumbar repositioning) 25/24 completed program (86%)
Vibe Fersum et al., 2013 Norway	Non-specific LBP for more than 3 months Pain-related movement behaviours N = 84 (45:39)	Directed at changing subject's individual cognitive, movement and lifestyle behaviours: explanation of vicious cycle of pain, specific movement exercises to normalize maladaptive behaviours, integration of daily living activities and physical activity programme 3 different private clinics Weeks 1–3, 1 session per week, weeks 4–12, 1 session every 2–3 weeks, 1 h first session, 30–45 min follow-ups. Home exercises on daily basis and daily diary outlining Joint mobilization or manipulation and general exercise or motor control exercise, 1 h first session, 30 min for follow-ups	At 3 and 12 months ODI, pain over last 2 weeks with PINRS, HSCL-25, FABQ, total lumbar spine range of motion, patient satisfaction, sick-leave days, care-seeking care between 3rd and 12th month 100% 45/39 completed program
Suni et al. 2006 Finland	LBP longer than 3 months without radiating pain neuromuscular fitness test N = 106 (52:54)	10 exercises of neuromuscular training and cognitive-behaviour learning were instructed; additionally, a book including information on lumbar neutral zones, instructions and pictures of the exercises and a log sheet for recording the dosage of the exercises was handed out 3 different workplaces Exercises should have been done twice a week, once guided through a physiotherapist and once independently over a period of 12 months No intervention	At 6 and 12 months VAS for past 7 days and for past 2 months, ODI, PDI, questionnaire on musculoskeletal symptoms; assessment of neuromuscular fitness 90% 40/45 completed program
Ng et al. 2015 Australia	LBP intensity of > 3/10 on VAS reached during a rowing training session 3-Space Fastrak system (collects spinal kinematics on the sagittal plane) N = 36 (17:19)	Individualised exercises based on clinical examination, assessing the primary contributing factors of LBP, including movements patterns, conditioning and lifestyle Initial session of 1 h, follow-up appointments were 30 min; after the first session rowers were seen a week after, then every 2 weeks local rowing clubs or university laboratory no intervention; participants remained free to seek treatment from other health practitioner; other treatment was not recovered	At end of program (8 weeks) and 12 weeks Pain intensity during 15 min ergometer trial, PSFS, RMDQ, lower limb muscle endurance, back muscle endurance 90% 15/18 completed program
Kent et al., 2015 Australia	Sub-acute (3–12 weeks) or chronic (> 12 weeks) LBP Assessment conducted through motion-sensor system N = 112 (58:54)	6 to 8 consultations over 10 weeks; guidelines-based care; individualised assessment to identify the primary movement dysfunction, consequently establishing a patient-specific rehabilitation strategy with detailed instructions in posture corrections, program of motion-sensor biofeedback alerts and individualised exercises; recalibration of the sensor at each treatment session 8 hospitals or outpatient primary care clinics 6 (sub-acute episode duration patients) or 8 (chronic episode duration patients) over a 10-week treatment period; wearing of the motion-sensor system for 4–10 h in ADL, during and after treatment session Guidelines-based care of LBP, wearing the motion-sensor system advice 6 to 8 times over the 10 weeks of treatment, sensors where turned off, no individualised feedback.	At end of the treatment and 12 months RMDQ, PSFS, QVAS, daily pain score, LBP analgesic use, number of pain/medication free days, LBP recurrence, time away from work, additional therapy, fear of movement, patient global impression of change 88% 44/48 completed program
Salamat et al., 2017, Iran	LBP more than 3 months Pain-related movement in extensions → active extension impairment N = 32 (16:16)	Movement control exercises as described by O'Sullivan Physiotherapy clinics (not specified) 8 sessions of 45 min supervised exercise therapy over a 4-week (2 sessions per week) period; control group: instruction of daily home-exercises Instruction of deep trunk stabilizing muscles, such as transversus abdominis, without contracting superficial trunk muscles and maintaining a normal breathing pattern; if the participant was able to hold isolated contraction for 10 s over 10 repetitions the exercises were improved e.g. with adding movements of the extremities	At end of program (4 weeks) Pain intensity with NRS, ODI, FRR (flexion relaxation ratio) of back extensors, 75% 12/12 completed program

Table 2
GRADE asessment.

Number of Studies	Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Quality of Evidence
Pain after treatment – no classification						
5 (Aasa et al., 2015; Henry et al., 2014; Jacobs et al., 2016; Kent et al., 2015; Suni et al., 2006)	No	No	Serious	Very Serious	Undetected	Very Low
Pain after treatment – classification						
4 (Salamat et al., 2017; Saner et al., 2015; Sheeran et al., 2013; Vibe Fersum et al., 2013)	No	Serious	No	Serious	Undetected	Low
Pain after 12 months – no classification						
3 (Aasa et al., 2015; Henry et al., 2014; Kent et al., 2015)	No	Serious	Serious	Very Serious	Undetected	Very Low
Pain after 12 months – classification						
2 (Saner et al., 2015; Vibe Fersum et al., 2013)	No	No	No	Serious	No	Moderate
Disability after treatment – no classification						
6 (Aasa et al., 2015; Henry et al., 2014; Jacobs et al., 2016; Kent et al., 2015; Ng et al., 2015; Suni et al., 2006)	No	No	Very Serious	Serious	Undetected	Very Low
Disability after treatment - classification						
5 (Lehtola et al., 2016; Salamat et al., 2017; Saner et al., 2015; Sheeran et al., 2013; Vibe Fersum et al., 2013)	No	Serious	No	No	Undetected	Moderate
Disability after 12 months – no classification						
3 (Aasa et al., 2015; Henry et al., 2014; Kent et al., 2015)	No	Serious	Very Serious	Very Serious	Undetected	Very Low
Disability after 12 months - classification						
3 (Lehtola et al., 2016; Saner et al., 2015; Vibe Fersum et al., 2013)	No	Serious	No	Very Serious	Undetected	Very Low

and six on disability at the 12-month follow-up: using the Oswestry Disability Index, Roland Morris Disability Index, or Patient-Specific Functional Scale.

At the end of treatment, four out of ten studies showed a treatment effect in favour of MVCE (95%CI not crossing zero). Six studies revealed no effect in either direction. The total effect over all studies showed a small effect in favour of MVCE treatment (SMD -0.38, 95%CI -0.68 to −0.09) (Fig. 4). Studies that restricted their sample to patients with MVCI showed a moderate effect in favour of MVCE treatment (SMD -0.66, 95%CI -1.18 to −0.13) (Fig. 4). Studies with an active control intervention showed a larger effect in favour of MVCE than studies with a non-intervention control group.

At the 12-month follow-up, three out of six studies showed a treatment effect in favour of MVCE (95%CI not crossing zero). Three studies revealed no effect in either direction. The total effect over all studies showed a small effect in favour of MVCE treatment (SMD -0.37, 95%CI -0.69 to −0.04) (Fig. 5). Studies that restricted their sample to patients with MVCI showed no tendency in favour of the MVCE intervention or the control intervention (SMD -0.50, 95%CI -1.10 - 0.01) (Fig. 5)

3.7. Heterogeneity of studies

All analyses revealed that the studies did not show a common effect ($p < 0.05$), with some proportions of the true effect falling into the moderate range ($T^2 = 0.10–0.20$) and a moderate proportion of the observed dispersion between studies being real and not due to random error ($I^2 = 62\%–73\%$) (Fig. 2–5). The studies with non-intervention control showed a common effect regarding disability after treatment ($p = 0.55$), as did the studies with no restriction of their sample for pain intensity after treatment and disability after treatment and after 12 months ($p = 0.09–0.49$). The studies with restricted samples showed a common effect for pain intensity after 12 months ($p = 0.22$). This implies that subgrouping the selected studies partially decreased the heterogeneity.

4. Discussion

The aim of this study was to determine the effect of MVCE treatment on disability and pain intensity for people with NSLBP and MVCI. Results show 'very low to moderate quality' evidence of a positive effect of MVCE on disability, both at the end of treatment and after 12 months (SMD -0.38 95%CI -0.68 -0.09 respectively −0.37 95%CI -0.61 -0.04). Pain was improved by MVCE at the end of treatment (SMD -0.39 95%CI -0.75 -0.04), but not after 12 months (SMD -0.27, 95%CI -0.63 0.09) ('very low to moderate quality' evidence). It is notable that the heterogeneity between studies was considerable. The studies indicating the greatest benefit had the common eligibility criteria of the participants having had NSLBP for more than 3 months (Aasa et al., 2015; Lehtola et al., 2016; Sheeran et al., 2013; Vibe Fersum et al., 2013). The studies favouring the control group treatment included participants with NSLBP for more than 12 months (Henry et al., 2014; Jacobs et al., 2016), except for one study which also included subacute pain (Saner et al., 2015). Pain duration could therefore affect disability. Half of the studies restricted their sample to patients suffering from MVCI, while the other half did not. Studies that did not restrict their sample showed a homogenous effect, favouring neither the MVCE intervention nor the control intervention. Studies that did restrict their sample to MVCI patients showed a more heterogeneous effect in favour of MVCE treatment.

Based on the available studies, it is difficult to assess the relative effectiveness of MVCE treatment compared to other interventions offered to people with NSLBP and MVCI. The alternative interventions compared in the included studies were diverse, including high-load lifting training, motor control exercises, general exercises, manual therapy or posture training. It was only possible to subgroup these studies based on active or non-intervention controls, but this failed to reduce the observed heterogeneity. The frequency, duration and intensity of the MVCE sessions could not be evaluated as those aspects also varied widely. Patient education was offered in most of the studies (Aasa et al., 2015; Vibe Fersum et al., 2013; Henry et al., 2014; Jacobs et al., 2016; Suni et al., 2006; Kent et al., 2015; Ng et al., 2015), but with differing content. Therefore, their effects cannot be judged.

A large body of research describes multiple interventions for the treatment of LBP, which primarily target impairments of body structure, function and limitations of activity or participation in people suffering from NSLBP. Generally, an early physical rehabilitation, or physiotherapy intervention, reduces the risk of a transition from acute to subacute or to chronic NSLBP (Gatchel et al., 2003; Gellhorn et al., 2012; Hagen et al., 2000; Linton et al., 1993; Nordeman et al., 2006; Pinnington et al., 2004; Wand et al., 2004; Kovacs et al., 2005). The European guidelines for the management of chronic NSLBP recommend exercise therapy as a first-line treatment (Airaksinen et al., 2006), since high-quality evidence suggests that it is more effective than other interventions for this condition (Hayden et al., 2005). In contrast, high-quality evidence on the effect of other interventions is often lacking

Table 3
PEDro scale.

Criteria	Aasa et al., 2015	Henry et al., 2014	Vibe Fersum et al., 2013	Lehtola et al., 2016	Jacobs et al., 2016	Saner et al., 2015	Sheeran et al., 2013	Suni et al., 2006	Ng et al., 2015	Kent et al., 2015	Salamat et al., 2017
1 Eligibility criteria were specified	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2 Subjects were randomly allocated to groups	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3 Allocation was concealed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No
4 Groups were similar at baseline	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5 There was blinding of all subjects	No	No	No	No	No	No	Yes	No	No	No	No
6 There was blinding of all therapists who administered therapy	No	No	No	No	No	No	No	No	No	No	No
7 There was blinding of all assessors who measured at least one key outcome	Yes	No	Yes	Yes	Yes	Yes	No	Yes	No	No	No
8 Measures of one key outcome were obtained from more than 85% of the subjects initially allocated to groups	No	Yes	No	Yes	Yes	Yes	No	No	Yes	No	No
9 All subjects received treatment or control condition as allocated or data for at least one key outcome was analysed by "intention to treat"	No	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes	No
10. The results of between-group statistical comparisons are reported for at least one key outcome	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
11. The study provides both point measures and measures of variability for at least one key outcome	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Total score out of 10 (No. 1. not included)	**6**	**7**	**6**	**8**	**8**	**8**	**6**	**6**	**6**	**5**	**4**

(Ebadi et al., 2014; Franke et al., 2015; Furlan et al., 2015a; Kalin et al., 2016; Macedo et al., 2016; Poquet et al., 2016; Rubinstein et al., 2013; Saragiotto et al., 2016b; Wegner et al., 2013; Yamato et al., 2016). The quality of evidence ranges from 'high to very low' that motor control exercises, spinal manipulation therapies, muscle energy techniques, therapeutic massage, therapeutic ultrasound, traction, or back schools provide similar outcomes to other forms of interventions, or, in some cases, to sham or non-interventions (Ebadi et al., 2014; Franke et al., 2015; Poquet et al., 2016; Rubinstein et al., 2013; Saragiotto et al., 2016b; Vickers and Zollman, 1999; Wegner et al., 2013). Our results indicate that when the studies address a prior restricted sample of NSLBP with MVCI, MCVE can be superior intervention compared to general exercises, weight training or stabilization training. Nevertheless, other factors, such as pain duration, seem equally important and vindicate future research.

As far as we know, this is the first systematic review and meta-analysis on this topic. However, similar studies have been conducted concerning motor control exercises (MCE) (Macedo et al., 2016; Saragiotto et al., 2016a). The difference between these two approaches is that the focus of MCE lies on the training of individual stabilizing muscles, such as transversus abdominis or multifidus. MVCI is a clinical feature of patients with LBP (O'Sullivan, 2005), who show aberrant and poorly-controlled active movements. In this review, we excluded studies in which the intervention group underwent MCE exercises. Nevertheless, some of the selected studies used MCE in the control group (Salamat et al., 2017; Henry et al., 2014; Jacobs et al., 2016). In these three studies, no significant differences for these two quite similar approaches were found. This makes sense, since the contrast between the groups is not large enough; certain exercises are very similar.

4.1. Limitations

The small sample sizes and the heterogeneity of the selected studies are limitations in this review, and reasons for caution when drawing conclusions. The constructs of impairments, activity limitations and participants' restrictions were summarized under the umbrella term of disability, according to the WHO definition (WHO). Studies show that the Roland Morris disability questionnaire, Oswestry disability questionnaire and patient-specific functional scale are comparable in measuring these activity restrictions and disabilities (Pengel et al., 2004; Leclaire et al., 1997; Chiarotto et al., 2016). Subgrouping disability into individual constructs would have resulted in smaller sample sizes for the meta-analyses of the subgroups. Through using the GRADE approach (Table 2.), it could be seen that many of the quality of evidence levels were 'low or very low'. Risk of bias was rated for most of the outcomes as 'not high', since nearly all the studies had a high PEDro score. However, because of inconsistency, indirectness and imprecision of many outcomes, we have serious concerns and low confidence in the presented data. This means that following studies may change the findings largely if the level of evidence is higher.

5. Conclusions

MVCE treatment may be more effective in improving disability in the short and long term for people with NSLBP and MVCI compared to other interventions. Pain was reduced through MVCE treatment in the short term, but not over the long term. The heterogeneity of the selected studies was considerable. This was somewhat reduced through subgrouping the studies according to their sample restrictions or control interventions. Therefore, other factors, such as pain duration, might be equally important and warrant future research. Larger and higher-quality RCTs with long-term follow-ups are recommended for future studies. Future research should pay close attention to the selection of participants with regard to duration of NSLBP and the presence of MVCI.

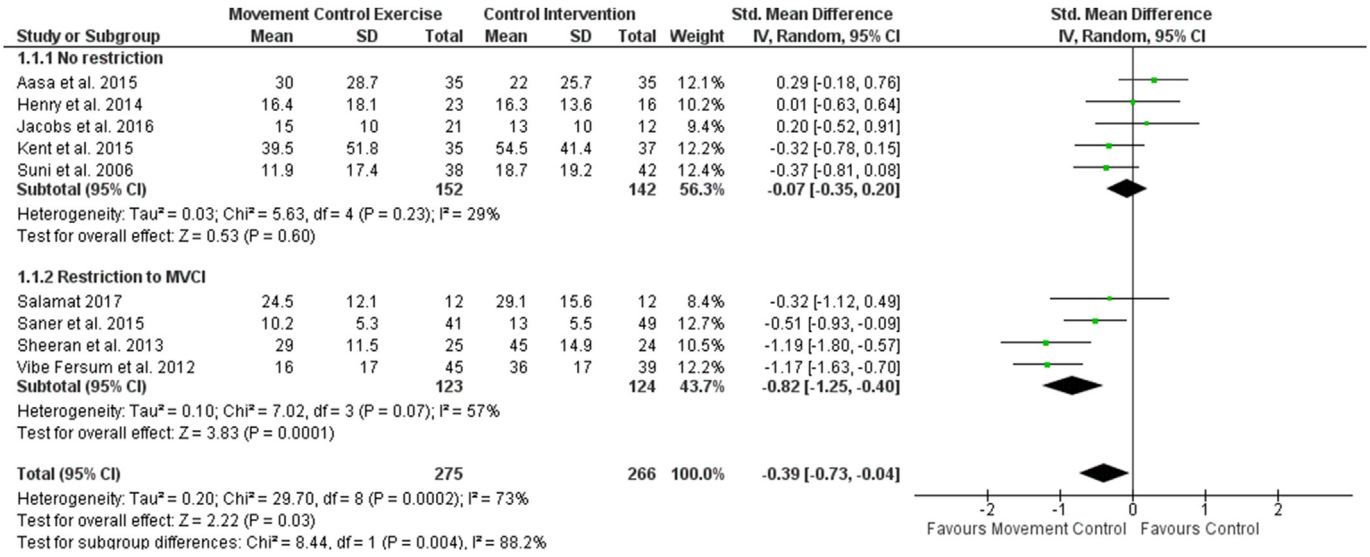

Fig. 2. Effects of MVCE intervention on pain intensity at the end of treatment, with or without sub-classification.

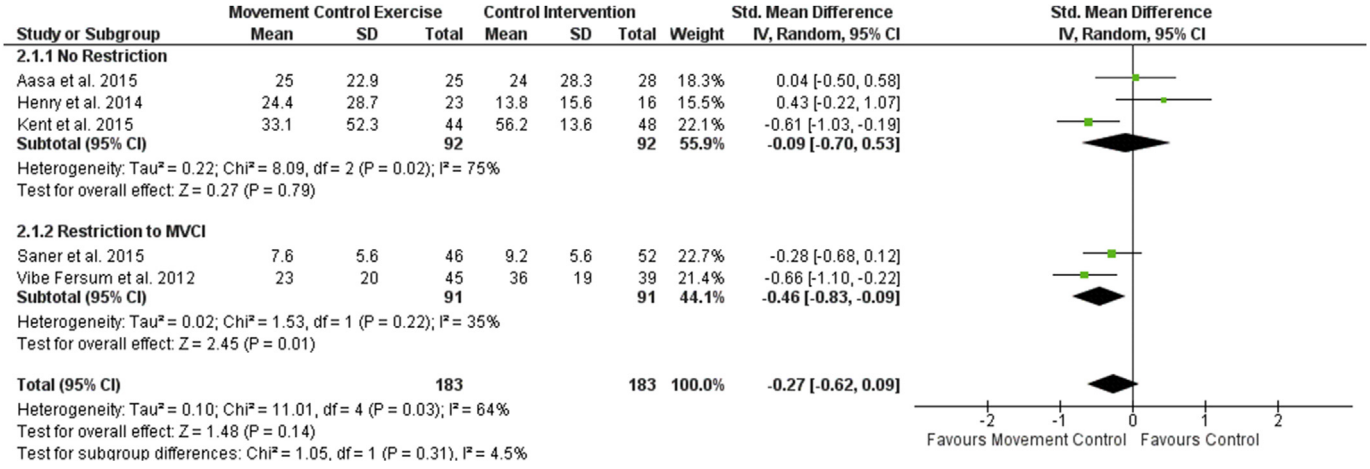

Fig. 3. Effect of MVCE intervention on pain intensity after 12 months or more, with or without sub-classification.

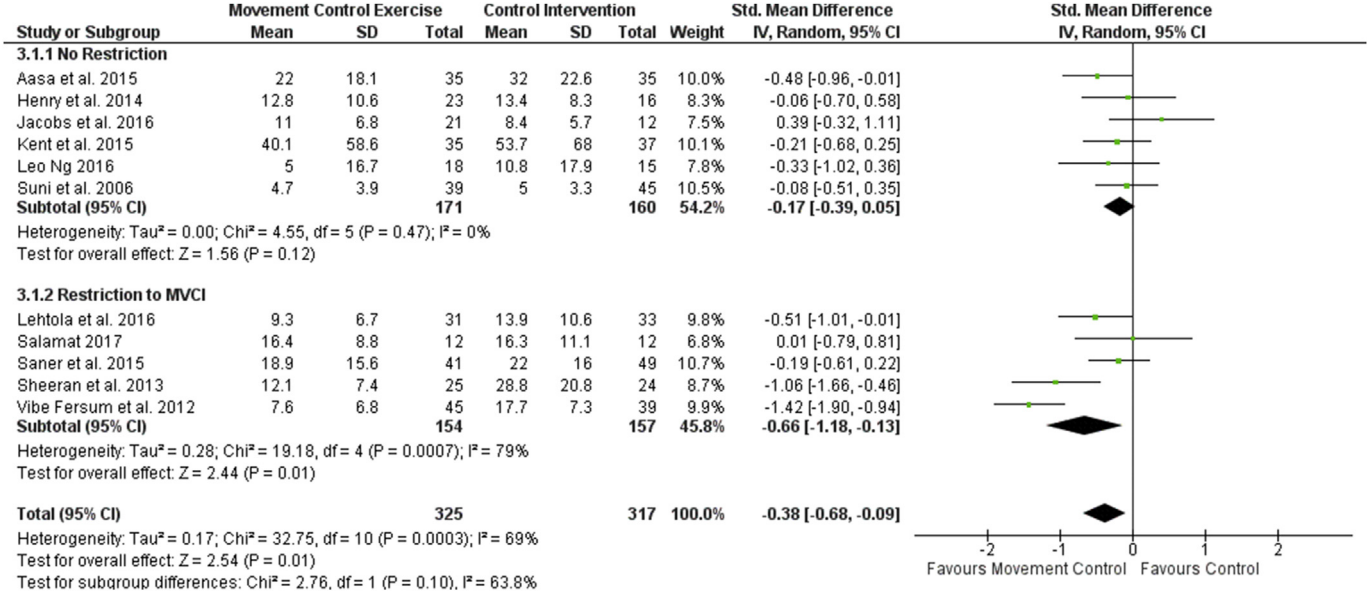

Fig. 4. Effect of MVCE intervention on disability at the end of treatment, with or without sub-classification.

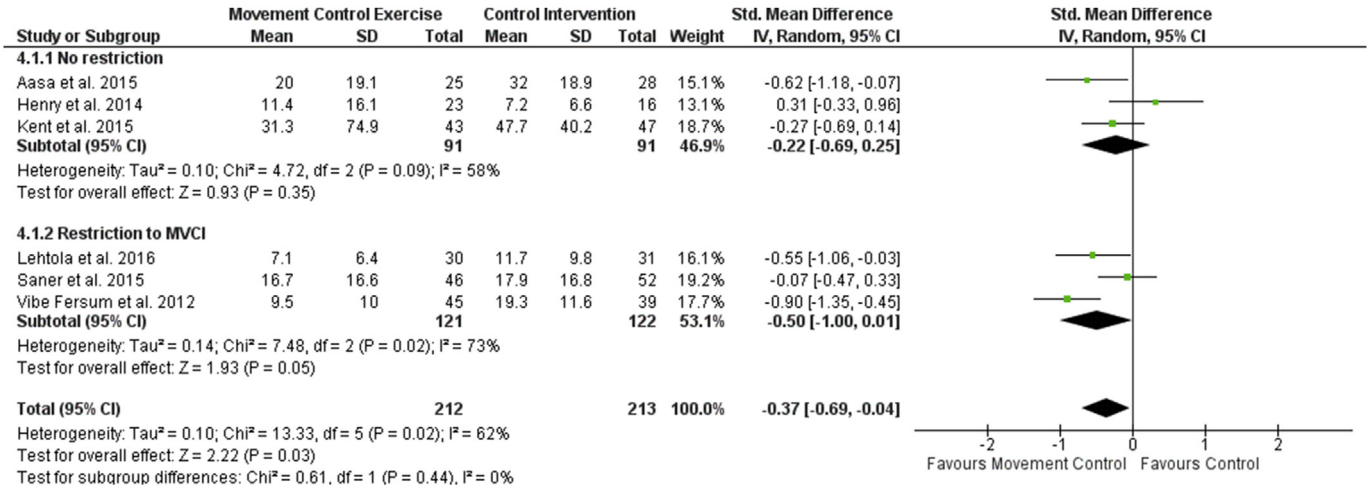

Fig. 5. Effect of MVCE intervention on disability after 12 months or more, with or without sub-classification.

Conflicts of interest

The authors declare that they have no competing interests.

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Author's contributions

HL and BB planned the study, made substantial contributions to the study concept, performed the literature search, collected data, screened and assessed the literature, and drafted the final manuscript. CB calculated the results for the meta-analysis, made substantial contributions to the study concept, verified the literature search and screening, and made the final assessment of literature eligibility. HL contacted the studies' main authors in the event of missing data and performed GRADE. SC searched the grey literature, assessed the literature, performed GRADE analysis and contributed to the manuscript. All authors read and approved the paper in its final version.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.msksp.2018.03.008.

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