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Effects of Pilates-Based Exercises on Pain and Disability in Individuals With Persistent Nonspecific Low Back Pain: A Systematic Review With Meta-analysis

Back pain is a common cause of disability and work loss, creating a large socioeconomic burden in developed countries.^{17,26,32,45} Between 60% and 80% of adults will be affected with low back pain during their lifetime.^{4,18} It has been reported that between 30% and 40% of individuals with acute low back pain never completely recover, developing chronic low



back pain.^{31,39} In addition to its high prevalence, the source of pain is not well-established in the majority of individuals with back pain, and the term “non-specific low back pain” is often used to describe this population.^{21,35,37}

In recent years, there has been a growing number of reports on the benefits of Pilates-based exercises for low back pain.^{7,13,14,20,24,29,42,43} Concomitantly, an increasing number of healthcare practitioners are using the Pilates-based approach for rehabilitation.³ Despite the limited number of randomized controlled trials investigating this exercise approach, proponents have claimed improved torso or core strength, with mentions of greater range of motion, muscle symmetry, flexibility,⁴² spinal and joint mobility, and proprioception, balance, and coordination.^{7,44}

In a previous systematic review, La Touche et al²⁷ highlighted the importance of distinguishing Pilates-based exercises from the classic Pilates Method. The Pilates Method is an exercise form that has been popular for decades among choreographers and dance instructors in the field of dance medicine,³ which addresses the causes of dance in-

● **STUDY DESIGN:** A systematic review with meta-analysis.

● **OBJECTIVES:** To compare pain and disability in individuals with persistent nonspecific low back pain who were treated with Pilates exercises compared to minimal or other interventions.

● **METHODS:** Searches of Medline, CINAHL, Embase, Cochrane library, PEDro, and ProQuest Dissertations and Thesis databases were conducted. Randomized controlled trials (RCTs) were selected and reviewed if they compared pain and disability in individuals with persistent nonspecific low back pain who were treated with Pilates exercises compared to other treatment approaches. Quality of the trials was evaluated. Data for pain and disability scores were extracted. Narrative synthesis plus meta-analyses were performed, with either a fixed-effects or random-effects model, standardized mean differences (SMDs), and tests for heterogeneity.

● **RESULTS:** Seven RCTs were identified and included in the meta-analyses. Data pooling was performed using RevMan 5. When compared to minimal intervention, Pilates-based exercise

provided superior pain relief (pooled SMD, -2.72; 95% CI: -5.33, -0.11; $P = .04$) but the pooled disability scores were not significantly different (pooled SMD, -0.74; 95% CI: -1.81, 0.33; $P = .17$). No significant differences were found when comparing Pilates-based exercise to other forms of exercise for pain (pooled SMD, 0.03; 95% CI: -0.52, 0.58; $P = .92$) or disability scores (pooled SMD, -0.41; 95% CI: -0.96, 0.14; $P = .14$).

● **CONCLUSION:** Pilates-based exercises are superior to minimal intervention for pain relief. Existing evidence does not establish superiority of Pilates-based exercise to other forms of exercise to reduce pain and disability for patients with persistent nonspecific low back pain. However, the relatively low quality of existing studies and the heterogeneity of pooled studies in this systematic review combine to suggest that these results should be interpreted with caution.

● **LEVEL OF EVIDENCE:** Therapy, level 1a-. *J Orthop Sports Phys Ther* 2011;41(2):70-80. Epub 22 October 2010. doi:10.2519/jospt.2011.3393

● **KEY WORDS:** exercise therapy, lumbar spine, rehabilitation

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juries, promotion of care, prevention, as well as safe postrehabilitation return to dance.³⁴ The neuromuscular demands of the traditional Pilates Method can be high, and, therefore, its application to physiotherapeutic interventions necessitates modifications.⁴¹ As such, the Pilates-based exercises, as described in the current literature, are adapted and simplified from the traditional Pilates Method, when used for rehabilitation purposes.^{20,27} The modified Pilates Method was designed with the intent to improve posture and control of movement⁴¹ via neuromuscular control techniques believed to improve lumbar spine stability through targeting the local stabilizer muscles of the lumbar-pelvic region or “core muscles.”^{20,41}

To date, there has been no meta-analysis that evaluates the effects of Pilates-based exercises on pain and disability in individuals with nonspecific chronic low back pain. In the 2 previously published systematic reviews of Pilates-based exercise,^{12,27} the authors reviewed the literature prior to November 2006²⁷ and October 2007,¹² respectively. da Silva and Mannrich¹² discussed the use of Pilates-based exercises for various rehabilitative purposes for different populations, while La Touche et al²⁷ included 3 trials that evaluated the use of Pilates-based exercises in individuals with nonspecific chronic low back pain. Both reviews used a simple descriptive approach to summarize their results.

Given the growing popularity of this approach, we believe that a meta-analysis was indicated to provide an updated review of the literature, incorporating new randomized controlled trials. In addition, a meta-analytical approach, which has not been used in the previously published reviews, can potentially add useful information about the magnitude of the effect of Pilates-based exercises on pain and disability. This approach has been reported to be superior to other forms of analysis for systematic reviews, as it provides treatment effect sizes with 95% confidence intervals (CIs).³³ Therefore, the objective

of this study was to systematically review randomized controlled trials comparing the effect of Pilates-based exercises (intervention) with other forms of interventions (comparisons) on pain and disability (outcomes) in individuals with persistent nonspecific low back pain (participants). We included trials that included individuals with low back pain persisting beyond the acute phase, defined as pain lasting longer than 4 weeks.⁹ This was based on guidelines suggesting that chronic and acute low back pain should be considered has separate entities.^{1,47}

METHODS

Search Strategy

WE SEARCHED MEDLINE (1966 to March 2009), CINAHL, EMBASE (1982 to March 2009), EBSCO host, PeDro, Cochrane library (Cochrane reviews, Cochrane central register of controlled trials), and ProQuest Dissertations and Theses databases for literature on the use of Pilates exercises for the treatment of individuals with chronic nonspecific low back pain. The search was also limited using the terms “Human” and “English language.” Initially we searched MEDLINE using the terms “low back pain,” “LBP,” “low back ache,” “back pain,” “backache,” “spine pain,” “Pilates,” “exercise therapy,” “randomized controlled trial,” “controlled clinical trial,” and/or “clinical controlled trial.” These steps were then repeated for the other databases. An example of the full electronic search strategy for MEDLINE is provided in **APPENDIX A**. We also reviewed the reference lists of the selected papers to further prevent any omissions.

The reviewers followed a selection process, defined prior to the beginning of the review, which included a checklist for inclusion criteria. Articles were eligible for inclusion if they were randomized controlled trials, included individuals with low back pain that persisted beyond the acute phase,⁹ assigned the experimental group to receive Pilates-based exercises only, assigned the comparison

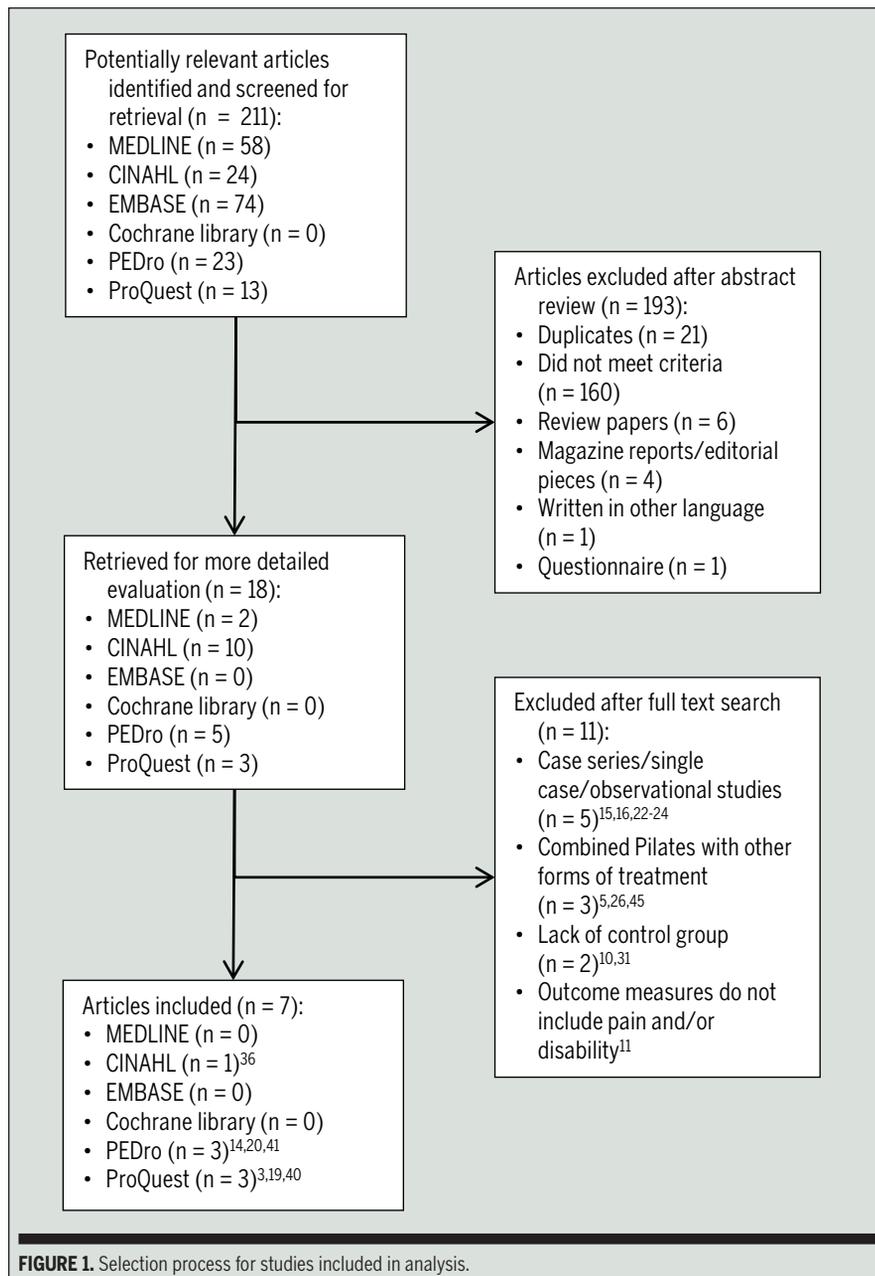
group to receive other forms of interventions other than Pilates-based exercises, and lastly, used outcome measures that included preintervention and postintervention pain and disability scores. Eligibility assessment for manuscript inclusion was performed independently by 2 reviewers (R.L.C.P. and A.Y.L.). Disagreements between reviewers were resolved by consensus.

Data Extraction and Quality Assessment

The methodological quality of the trials was assessed using the 9-item Delphi List⁴⁸ (**APPENDIX B**). Assessment of quality of trials was performed by 2 independent reviewers (R.L.C.P. and A.Y.L.), and disagreements were resolved by 2 other reviewers (E.C.W.L. and W.P.W.). We assessed the methodological quality of the studies by evaluating the domains of population, treatment allocation, blinding, prognostic comparability, and analysis. Using a standardized extraction form, information on characteristics of trial participants (age, gender, and duration of complaint), details of intervention (frequency per week and duration per session), and preoutcome and postoutcome measures (pain and disability) was extracted from each included trial. Outcomes that were closer to the end of treatment were used whenever there were multiple time points within a study. When there was inadequate information about outcomes to allow data analysis, the authors of the study were contacted. Of the 7 authors who were contacted, 3 replied to our inquiries.^{14,36,40} Risk of bias (eg, blinding of treating therapist/patient/outcome assessor), dropout rate, and analysis of all participants as randomized were also assessed across the studies.

Quantitative Data Synthesis and Analysis

Reliability analyses of interrater agreement were performed with SPSS 14.0 (SPSS Inc, Chicago, IL) for Windows (Microsoft Corp, Redmond, WA). Interrater reliability was reported for the total quality score with Kappa statistics,²⁸ and was interpreted as poor (<0.00), slight



vention (control arm) strata were then analyzed to make the control arm more comparable to the Pilates-based exercise arm. For example, trials in which participants continued with usual care or activities of daily living when assigned to the control groups were grouped as “Pilates versus minimal intervention.” In contrast, trials in which participants performed exercises (other than Pilates-based exercises) when assigned to the control groups were grouped as “Pilates versus other forms of exercise.” The differences were calculated such that negative differences indicated that results favored Pilates-based exercises, while positive differences indicated that the results favored the alternate intervention (ie, minimal intervention, other forms of exercise, etc). For all analyses, significance was set at $P < .05$. To assess the risk of publication bias (resulting from nonpublication of small trials with negative results), we also plotted SMD versus standard error (SE) for both pain and disability scores.³⁰ The symmetry of such “funnel plot” was assessed visually.³⁰ A funnel plot is a scatter plot of intervention effect against a measure of study size. It is used primarily as a visual aid in detecting bias or systematic heterogeneity. A symmetric inverted funnel shape arises from a “well-behaved” data set in which publication bias is unlikely. An asymmetric funnel indicates a relationship between intervention effect and study size. This suggests the possibility of either publication bias or a systematic difference between smaller and larger studies (“small study effects”).

RESULTS

Study Selection

THE INITIAL ELECTRONIC DATABASE search resulted in a total of 211 articles. **FIGURE 1** shows the flow of papers through the review. Of these, 18 were selected for detailed review, with only 7 eligible for inclusion in the final analysis (**FIGURE 1**). Reasons for exclusion included case series/single case/observational studies,^{15,16,22-24} combined Pilates

(0.00-0.20), fair (0.21-0.40), moderate (0.41-0.60), substantial (0.61-0.80), or almost perfect (0.81-1.0).

We used formal meta-analytical techniques for pooling results wherever possible, using RevMan 5 (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark). To account for differing outcome scales used among studies, we calculated standardized mean differences (SMDs) for pain and disability scores, their 95% confi-

dence intervals (CIs), and performed tests of heterogeneity (χ^2). The I^2 statistic was used to measure the extent of between-trial heterogeneity. Fixed-effects or random-effects models were used as appropriate and were based on our interpretation of commonality of effect size.⁶ For example, data were pooled using a random-effects model, if trials differed in ways that might have plausibly impacted on the pooled outcome.⁶

Subgroup analyses based on inter-

TABLE 1

DETAILS OF THE INCLUDED RANDOMIZED CONTROLLED TRIALS

Authors (Year)	Intervention (n)	Outcome Measures*		Results	Score [†]
		Preintervention	Postintervention		
Anderson (2005) ³	<ul style="list-style-type: none"> Pilates (n = 10) Therapeutic massage (n = 11) 	<ul style="list-style-type: none"> Pilates: MBI-pain, 33.5 ± 18.6; ODI, 16.7 ± 4.2 Therapeutic massage: MBI-pain, 39.3 ± 15.6; ODI, 18.5 ± 5.9 	<ul style="list-style-type: none"> Pilates: MBI-pain, 24.2 ± 14.7; ODI, 13.9 ± 5.7 Therapeutic massage: MBI-pain, 35.0 ± 18.0; ODI, 17.9 ± 7.2 	No significant decrease in pain from preintervention to postintervention, but 27.8% and 10.9% decrease noted in Pilates and massage, respectively. No significant decrease in ODI from preintervention to postintervention, but 16.8% and 3.2% decrease noted in Pilates and massage, respectively.	5
Donzelli et al (2006) ⁴⁴	<ul style="list-style-type: none"> Pilates CovaTech[‡] (n = 18) Back School (n = 22) 	<ul style="list-style-type: none"> Pilates CovaTech: VAS, 7.35 ± 2.25; ODQ, 13.6 ± 7.0 Back School: VAS, 6.8 ± 3.1; ODQ, 10.0 ± 6.5 	<ul style="list-style-type: none"> Pilates CovaTech: VAS, 4.55 ± 2.16; ODQ, 6.9 ± 3.9 Back School: VAS, 4.35 ± 3.05; ODQ, 7.7 ± 6.2 	Significant decrease in both VAS and ODQ within each group from preintervention to postintervention. But comparison between the groups was not done.	3
Gagnon (2005) ¹⁹	<ul style="list-style-type: none"> Pilates (n = 6) Traditional lumbar stabilization exercise (n = 6) 	<ul style="list-style-type: none"> Pilates: VAS, 2.01 ± 1.72; ODI, 15.8 ± 3.71 Traditional lumbar stabilization exercise: VAS, 3.85 ± 2.52; ODI, 17.2 ± 6.11 	<ul style="list-style-type: none"> Pilates: VAS, 0.98 ± 1.71; ODI, 7.0 ± 5.9 Traditional lumbar stabilization exercise: VAS, 1.53 ± 1.77; ODI, 9.17 ± 7.5 	Significant decrease in VAS and ODI within each group from preintervention to postintervention, but no significant difference between both groups.	3
Gladwell et al (2006) ²⁰	<ul style="list-style-type: none"> Pilates (n = 20) Control (n = 14) 	<ul style="list-style-type: none"> Pilates: RMVAS, 2.7 ± 0.9; ODQ, 19.7 ± 9.8 Control: RMVAS, 2.4 ± 0.9; ODQ, 24.1 ± 13.4 	<ul style="list-style-type: none"> Pilates: RMVAS, 2.2 ± 0.9; ODQ, 18.1 ± 11.2 Control: RMVAS, 2.4 ± 0.8; ODQ, 18.1 ± 13.0 	Significant decrease in RMVAS, but no significant decrease in ODQ, from preintervention to postintervention.	5
O'Brien et al (2006) ³⁶	<ul style="list-style-type: none"> Pilates (n = 8) Standard physiotherapy (n = 9) Control (n = 9) 	<ul style="list-style-type: none"> Pilates: VAS, 61.6 ± 6.5; RMDQ, 10.7 ± 1.91 Standard physiotherapy: VAS, 54.7 ± 6.5; RMDQ, 9.5 ± 1.81 Control: VAS, 48.7 ± 6.2; RMDQ, 7.0 ± 1.91 	<ul style="list-style-type: none"> Pilates: VAS, 17.2 ± 7.7; RMDQ, 1.72 ± 0.77 Standard physiotherapy: VAS, 17.8 ± 6.9; RMDQ, 4.2 ± 1.5 Control: VAS, 52.0 ± 7.3; RMDQ, 6.2 ± 1.5 	Significant difference between combined treated groups (ie, Pilates and standard physiotherapy) and control group. But no significant difference between Pilates and Standard physiotherapy group.	6
Quinn (2005) ⁴⁰	<ul style="list-style-type: none"> Pilates-based mat exercise (n = 15) Control (n = 7) 	<ul style="list-style-type: none"> Pilates-based mat exercise: ODQ, 25.9 ± 10.7 Control: ODQ, 22.0 ± 8.7 	<ul style="list-style-type: none"> Pilates-based mat exercise: ODQ, 10.9 ± 10.3 Control: ODQ, 18.0 ± 12.4 	Significant decrease in ODQ in Pilates-based mat exercise group from preintervention to postintervention.	4
Rydeard et al (2006) ⁴¹	<ul style="list-style-type: none"> Specific exercise training (n = 21) Control (n = 18) 	<ul style="list-style-type: none"> Specific exercise training: NRS-101, 23.0 ± 1.79; RMDQ, 3.1 ± 2.75 Control: NRS-101, 30.4 ± 1.78; RMDQ, 4.2 ± 3.39 	<ul style="list-style-type: none"> Specific exercise training: NRS-101, 18.3 ± 1.47; RMDQ, 2.0 ± 1.37 Control: NRS-101, 33.9 ± 1.48; RMDQ, 3.2 ± 1.7 	Significant decrease in both NRS-101 and RMDQ in specific exercise-training group from preintervention to postintervention.	6

Abbreviations: MBI-pain, Miami Back Index pain subscale (range, 0-100, with higher scores indicating greater perception of pain limiting activity); NRS-101, 101-point numerical rating scale (range, 0-100, with higher scores indicating greater levels of pain); ODI, Oswestry Disability Index (range, 0%-50%, with higher scores indicating greater limitation in activity level); ODQ, Oswestry Disability Questionnaire (range, 0%-50%, with higher scores indicating greater limitation in activity level); RMVAS, Roland Morris Visual Analogue Scale (range, 0-10, with higher scores indicating greater levels of pain); RMDQ, Roland Morris Disability Questionnaire (range, 0-24, with higher scores indicating greater levels of disability).

*Values are mean ± SD.

[†]Score based on The Delphi List⁴⁸ (0-9), with higher scores indicating better methodological qualities of trials.

[‡]Pilates CovaTech (taken from the name of the therapist who invented it) is a specific rehabilitation method derived from the original Pilates method in Italy. Such rehabilitation program follows the basic principles of the Pilates method.

with other forms of intervention,^{5,26,45} lack of a comparison group,^{10,31} and outcome measures not including pain and/or disability.¹¹ All 7 papers included in the review and meta-analysis were randomized controlled trials.

Methodological Quality

Agreement among the 2 reviewers was almost perfect ($\kappa = 0.85$, $P < .001$).²⁸ The methodological quality assessment using the Delphi List⁴⁸ revealed a mean score of 4.6, with a range of scores from 3 to 6

(TABLE 1). Blinding of treating therapists and patients was not achieved in most of the trials, but more than half of the trials used blinding of outcome assessors. Four of the 7 trials^{2,19,20,40} had dropout rates of at least 30%. Intention-to-treat

[LITERATURE REVIEW]

TABLE 2

DETAILS OF PATIENT CHARACTERISTICS AND INTERVENTION IN THE INCLUDED RANDOMIZED CONTROLLED TRIALS

Authors (y)	Patient characteristics	Intervention
Anderson (2005) ³	<ul style="list-style-type: none"> Source of recruitment: local clinicians (ie, physicians, surgeons, etc) who treat low back pain Mean age: Pilates, 42.4 y; therapeutic massage, 44.0 y Gender: 11 males, 10 females. Groups comparable at baseline Duration of complaint (mean ± SD): Pilates, 18.1 ± 27.0 mo; massage, 58 ± 103.7 mo 	<ul style="list-style-type: none"> Pilates: 12 sessions (50 min each) over 6 wk, reformer exercises in 6 possible positions, with progression through graded strengthening and awareness program Therapeutic massage: 12 sessions (30 min each) over 6 wk, effleurage, pétrissage, and deep tissue friction massage
Donzelli et al (2006) ¹⁴	<ul style="list-style-type: none"> Source of recruitment: outpatient departments Mean age: Pilates CovaTech,* 48.9 y; Back School, 51.25 y Gender: Pilates CovaTech, 6 males, 12 females; Back School, 8 males, 14 females Duration of complaint: >3 mo for both groups 	<ul style="list-style-type: none"> Pilates CovaTech: 10 consecutive sessions, 1 h each, postural/breathing education, search for neutral position and sitting/antalgic/stretching/ proprioceptivity improvement exercises Back School: 10 consecutive sessions, 1 h each, respiratory education, postural education/muscular strengthening/mobilizing exercises
Gagnon (2005) ¹⁹	<ul style="list-style-type: none"> Source of recruitment: outpatient orthopaedic physical therapy rehabilitation facility Mean age: Pilates, 36.0 y; traditional lumbar stabilization exercise, 30.3 y Gender: Pilates, 1 male, 5 females; traditional lumbar exercises, 2 males, 4 females Duration of complaint: >3 mo in 9 participants, <3 mo in 3 participants 	<ul style="list-style-type: none"> Pilates: 10.5 sessions, 30-45 min each, over 7.33 wk; Pilates mat exercises Traditional lumbar stabilization exercise: 9.67 sessions, 30-45 min each, over 6.58 wk, mat lumbar stabilization
Gladwell et al (2006) ²⁰	<ul style="list-style-type: none"> Source of recruitment: local doctor's clinics and local university Mean age: Pilates, 36.9 y; control, 45.9 y; significant difference between groups Gender: Pilates, 3 males, 17 females; control, 4 males, 10 females Duration of complaint (mean ± SD): Pilates, 115 ± 101 mo; control, 139 ± 148 mo 	<ul style="list-style-type: none"> Pilates: 6 sessions, 1 h each, over 6 wk, Pilates exercises (posture check, recruitment of "core muscles," etc) Control: over 6 wk, continue with normal activities and pain relief
O'Brien et al (2006) ³⁶	<ul style="list-style-type: none"> Source of recruitment: medical general practitioner (GP) clinics Mean age: Pilates, 33.8 y; standard physiotherapy, 39.4 y; control, 38.9 y Gender: Pilates, 7 males, 2 females; standard physiotherapy, 6 males, 4 females; control, 6 males, 3 females Duration of complaint (mean ± SD): overall, 10.9 ± 7.7 mo 	<ul style="list-style-type: none"> Pilates: 8 sessions, 1 h each, over 4-6 wk, Pilates based on the official body control Pilates manual by Robinson et al,[†] home exercises prescribed after fourth session. Standard physiotherapy: 8 sessions, ½ h each, over 4-6 wk, manual therapy, education, core stability exercises, stretches, McKenzie, interferential, orthotics, taping and/or laser Control: no treatment but it is offered upon completion of study
Quinn (2005) ⁴⁰	<ul style="list-style-type: none"> Source of recruitment: local commercial and community fitness centers Mean age: Pilates-based mat exercises, 46.3 y; control, 34.7 y Gender: not accounted for Duration of complaint: not accounted for but ensured that all were 6 mo at least 	<ul style="list-style-type: none"> Pilates-based mat exercise: 24 sessions, 45-60 min each, over 12 wk, Pilates-based mat exercises Control: over 12 wk, continue with normal daily activities without commencing any exercise program
Rydeard et al (2006) ⁴¹	<ul style="list-style-type: none"> Source of recruitment: private and public physicians' and physiotherapists' offices, local sports clubs and Universities Mean age: specific exercise training, 37.0 y; control, 34.0 y Gender: specific exercise training, 6 males, 12 females; control, 8 males, 13 females Duration of complaint (mean [range]): specific exercise training, 66 (6-324) mo; control, 108 (12-240) mo 	<ul style="list-style-type: none"> Specific exercise training: 12 sessions, 1 h each, over 4 wk, Pilates exercises Control: over 4 wk, continued with usual care, which is defined as consultation with physician and other specialists and healthcare professionals, as necessary

*Pilates CovaTech (taken from the name of the therapist who invented it) is a specific rehabilitation method derived from the original Pilates method in Italy. Such rehabilitation program follows the basic principles of the Pilates method.

†Robinson L, Fisher H, Knox J, et al. Official Body Control Pilates Manual. London, UK: Pan Macmillan; 2002.

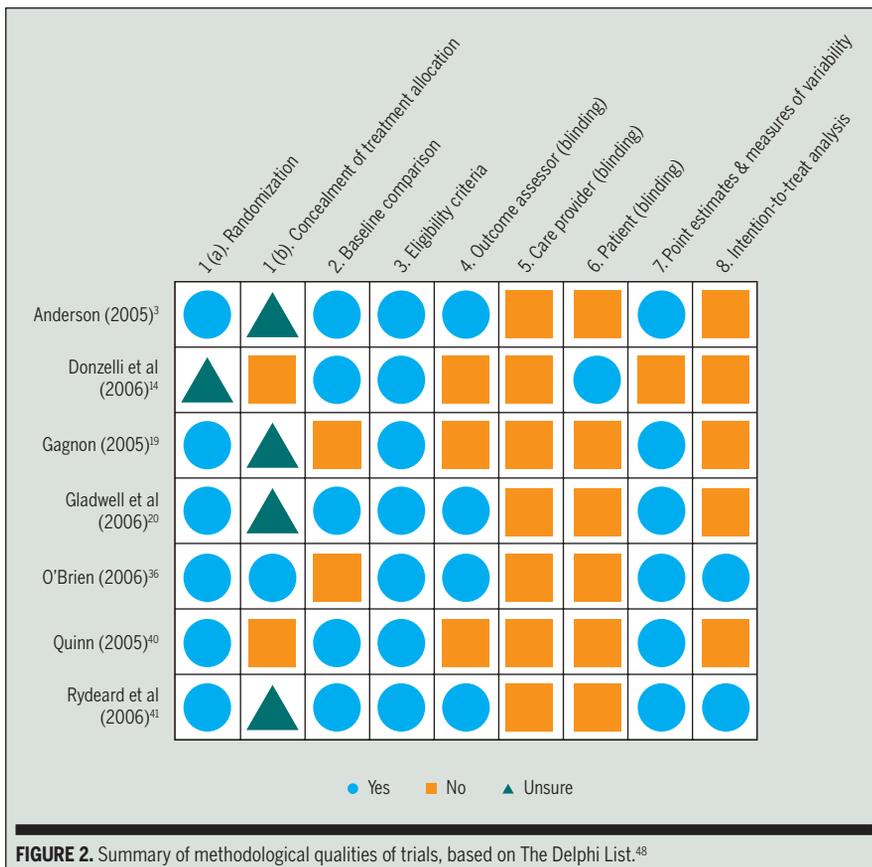
analysis was performed in 2 of the trials (FIGURE 2).^{36,41}

Study Characteristics

The 7 trials included in this review compared Pilates exercises in individuals with persistent nonspecific low back pain

versus a different intervention approach. One trial (21 patients) compared Pilates with passive intervention.² Two trials (52 patients) compared Pilates with other forms of exercises.^{14,19} Three trials (95 patients) compared Pilates with other forms of minimal intervention (ie,

usual care or continue with daily activities).^{20,40,41} One trial (26 patients) compared Pilates with 2 other intervention groups: physical modalities with exercises and minimal intervention (TABLE 2).³⁶ The funnel plots for both pain intensity (FIGURE 3A) and disability (FIGURE



3B) showed evidence of asymmetries.

Pain Score

One of the trials did not measure pain as an outcome measure.⁴⁰ As such, 6 trials (total of 83 individuals receiving Pilates and 80 receiving a different intervention) were included in the analysis.^{2,14,19,20,36,41} Data for pain scores in 3 trials^{20,36,41} that compared Pilates with minimal intervention and 2 trials^{14,19} that compared Pilates with other forms of exercise were pooled using a random-effects model, based on the assumption that the Pilates-based exercises and minimal intervention in these trials might differ in ways that could impact on the results.⁶ Pooled SMDs of -2.72 (95% CI: $-5.33, -0.11$), with a high level of heterogeneity ($I^2 = 94\%$, $\tau^2 = 4.86$, $\chi^2 = 33.12$, $df = 2$, $P < .00001$), and 0.03 (95% CI: $-0.52, 0.58$), with a low level of heterogeneity ($I^2 = 0\%$, $\tau^2 = 0.00$, $\chi^2 = 0.60$, $df = 1$, $P = .44$), were found when comparing Pilates exercises to minimal

intervention and other forms of exercises, respectively (FIGURE 4). The 95% CI did not include zero when Pilates-based exercises were compared to minimal intervention, suggesting greater improvement of pain with the Pilates-based exercises.

Disability Score

Five trials (total of 69 individuals receiving Pilates and 60 individuals receiving an alternate intervention) used the Oswestry disability scores as the outcome measure for disability.^{2,14,19,20,40} The other 2 trials (total of 29 individuals receiving Pilates and 27 individuals receiving an alternate intervention) used Roland-Morris disability scores.^{36,41} Data for disability scores were standardized. Data for disability scores in 4 trials^{20,36,40,41} that compared Pilates with minimal intervention and 2 trials^{14,19} that compared Pilates with other forms of exercise were pooled using a random-effects model. Pooled SMDs of -0.74 (95% CI: $-1.81,$

0.33), with a high level of heterogeneity ($I^2 = 84\%$, $\tau^2 = 0.95$, $\chi^2 = 18.26$, $df = 3$, $P = .0004$), and -0.41 (95% CI: $-0.96, 0.14$), with a low level of heterogeneity ($I^2 = 0\%$, $\tau^2 = 0.00$, $\chi^2 = 0.40$, $df = 1$, $P = 0.52$), were found when comparing Pilates exercises to minimal intervention and other forms of exercises, respectively (FIGURE 5). The 95% CIs include 0 for both comparisons, failing to support greater reduction of disability using Pilates-based exercises compared to other forms of exercises or minimal intervention.

DISCUSSION

RESULTS FROM THIS REVIEW SUGGEST that Pilates-based exercises are superior to minimal intervention for reduction of pain in individuals with non-specific low back pain. However, Pilates-based exercises were no more effective than other forms of exercise to reduce pain. In addition, the Pilates exercises were no more effective than minimal intervention or other exercise interventions to reduce disability related to chronic low back pain. These conclusions must be interpreted with the acknowledgement of the limited number of trials included in this meta-analysis, the limited number of participants in each trial, the clinical heterogeneity across the trials, and the heterogeneity of the individuals within each trial.

It is noteworthy that there were slight variations in emphasis during Pilates-based exercises across the trials. For example, Rydeard et al⁴¹ emphasized specific-activation strategies of the gluteus maximus. Conversely, Anderson² emphasized the dissociation of hips from the spine and stabilization of the pelvis during the initial weeks of therapy, followed by the addition of spring resistance during the Pilates-based exercises. Finally, other authors^{19,20,40} focused on targeting the “core muscles,” especially the transversus abdominis and multifidi. Gladwell et al²⁰ and Gagnon¹⁹ also gradually used more dynamic movements to increase the complexity of the Pilates-based exercises.

The individuals with persistent non-specific low back pain who participated in the studies included in this review could be considered a heterogeneous group. Individuals with varying duration of symptoms may respond differently to Pilates-based exercises, such that the effects in different directions for these subgroups combine to give the impression of no effect for the combined group (washout effect).⁴⁶ This would also suggest that Pilates-based exercises may not be appropriate for all individuals. Unfortunately, there is no available data on adverse events in the literature.⁸ Nonetheless, from a clinical perspective, these exercises should be prescribed judiciously, modified appropriately, and taught by individuals properly trained to teach Pilates.

La Touche et al²⁷ pointed out that it would be important to determine if Pilates performed on mats is more effective or adequate than Pilates performed using machines or vice versa. In this review, some studies involved the use of reformers,^{2,41} while others used mats.^{19,20,40} Anderson² suggests that the use of the reformer is to help those who are unable to do the Pilates-based mat exercises. Pilates-based exercises performed on the mat may be difficult to some people due to the effect of gravity.³ As such, springs on an apparatus, such as the reformer, can be used to assist an injured individual to perform the movements successfully, with the goal of reaching safe recovery.³ We were unable to determine if all individuals in the trials that used the mats were able to perform the Pilates-based mat exercises. This might explain the high dropout rate in those trials which studied Pilates-based mat exercises.^{19,20,40} While 4 studies^{2,20,36,41} used blinding of outcome assessors, intention-to-treat analysis was not performed in 5 of the trials,^{2,14,19,20,40} despite the 30% or more of individuals in these trials who did not complete the study. Anderson² reported a 32.3% (10/31) dropout rate, Gagnon¹⁹ a 42.9% (9/21) dropout rate, Gladwell et al²⁰ a 30.6% (15/49) dropout rate, and

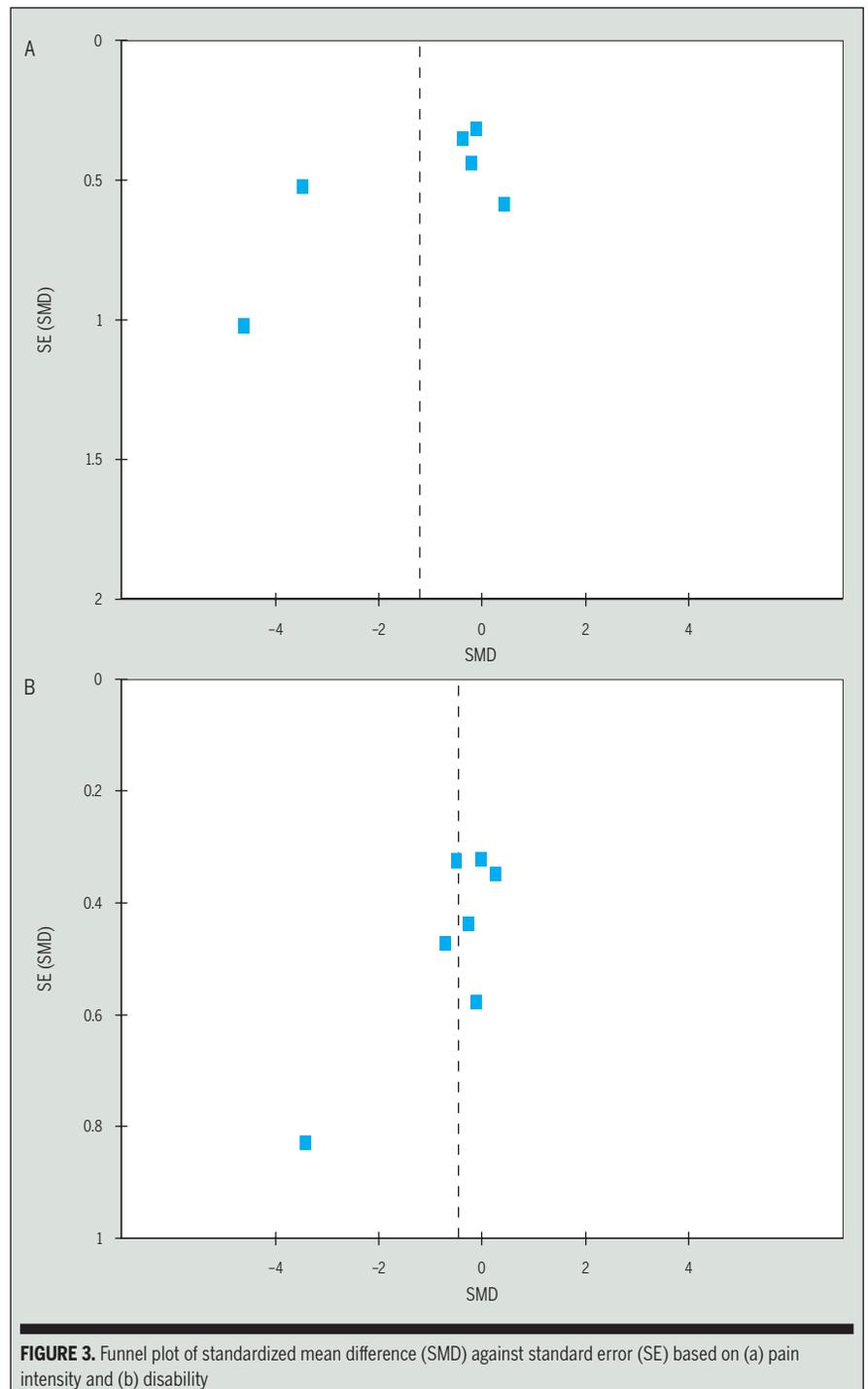
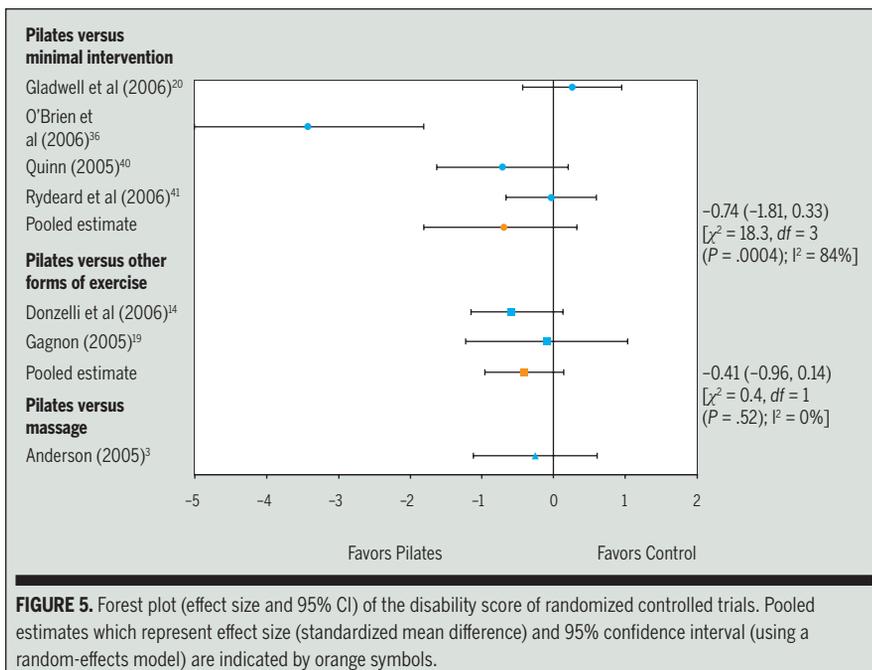
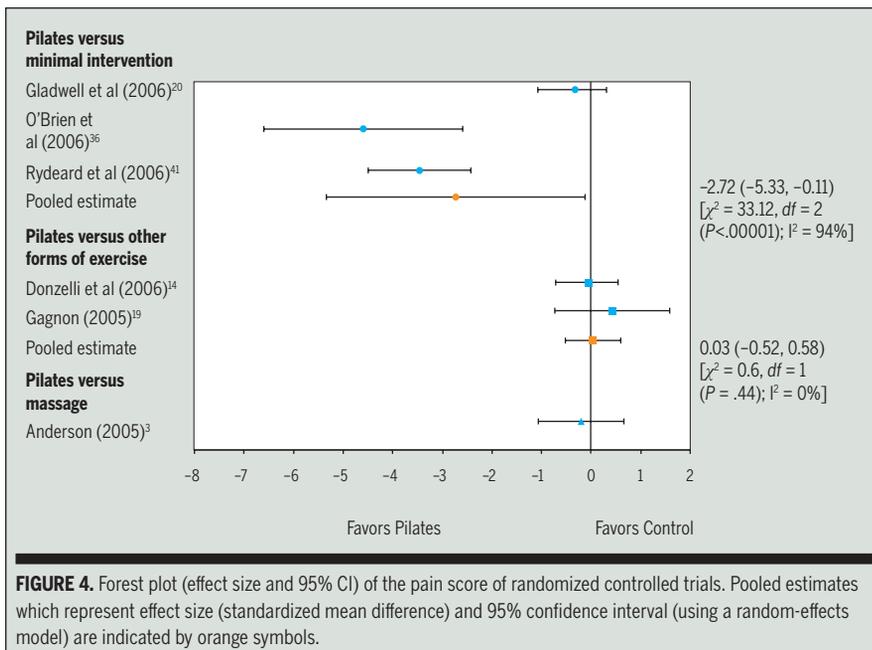


FIGURE 3. Funnel plot of standardized mean difference (SMD) against standard error (SE) based on (a) pain intensity and (b) disability

Quinn⁴⁰ a 31.3% (10/31) dropout rate. We have to be mindful that intention-to-treat analysis holds the randomization as of paramount importance as deviation from the original randomized groups secondary to high dropout rates could potentially contaminate the treatment

comparison.^{25,49} As such, all randomized patients in the groups to which they were randomly assigned should be included (ie, “as randomized, so analysed”⁴⁹). This is regardless of the treatment the patients actually received and subsequent withdrawal from treatment.⁴⁹ In addition,



tion, this approach would more likely reflect the actual efficacy of an intervention in clinical practice.²⁵ For example, Rydeard et al⁴¹ reported missing follow-up data for some participants, albeit all individuals completed the initial 4-week treatment intervention, according to the study protocol. Nonetheless, they analyzed the missing data using 3 different approaches to intention-to-treat analy-

ses to verify the robustness of their conclusion, including best- and worst-case scenarios.

The individuals with nonspecific chronic low back pain in most of the studies received 8 to 12 sessions^{2,14,19,36,41} of Pilates-based exercises at a frequency of 1 to 2 times per week^{2,19,20,36,40} over a span of 6 to 8 weeks.^{2,19,20,36} However, there were large variations in frequen-

cy of home exercises performed by the participants within the trials, as well as the compliance rate among the trials. It has been reported that noncompliance with home exercises was associated with poorer long-term outcome in patients with chronic low back pain.³⁸ As such, compliance with home exercises should be viewed as an important confounding factor. Four of the 7 trials included in this analysis monitored compliance through the use of journals,¹⁹ diaries,²⁰ and log sheets.⁴¹ Gladwell et al²⁰ reported a high compliance rate with 90% (18/20) of the participants in the Pilates group performing home exercises twice per week and 100% performing home exercises at least once a week. Gagnon¹⁹ reported that some of their participants performed the home exercises 1 to 3 times a week while some did so 5 to 6 times a week. Rydeard et al⁴¹ reported "good" compliance, based on a verbal report from the treating physiotherapist. Lastly, Donzelli et al¹⁴ reported better compliance to home exercises in the Back School group (45.45%) compared to the Pilates group (28.57%). However, only 4.5% of the Back School group and 9.5% of the Pilates group performed their respective exercises on a regular basis.

Many studies did not have sufficient follow-up to determine medium-term or long-term benefits of Pilates on chronic low back pain. O'Brien et al³⁶ reported pain scores during follow-up at 6 weeks, while Rydeard et al⁴¹ reported disability scores at 3, 6, and 12 months. In addition, Donzelli et al¹⁴ reported pain and disability scores at 3 and 6 months. O'Brien et al³⁶ reported no statistically significant difference in pain intensity ($P = .97$) between the Pilates and standard physiotherapy group during the 6-week follow-up, while Rydeard et al⁴¹ reported improved disability scores for up to 12 months following Pilates-based therapeutic exercises. Lastly, reduced pain and disability scores for up to 6 months were noted in the study by Donzelli et al.¹⁴

This review has some limitations that need to be acknowledged. The quality of

the included studies varied. In addition, publication bias might have accounted for the effect size we observed, in view of the language restriction applied during our search strategy. This could have explained the asymmetries found in our funnel plots (FIGURE 3). However, we used a comprehensive search strategy. Furthermore, reasons for study exclusions were clearly documented and attempts were made to identify unpublished studies via ProQuest Dissertations and Theses database during our search. In addition, the clinical heterogeneity among studies, particularly with respect to Pilates intervention and chosen control/comparison intervention, poses a challenge. A certain amount of diversity among the studies may be inevitable, yet grouping the studies allowed reporting a summary effect, combining the data from the individual studies.⁶ Because all of the studies met our inclusion criteria and most had similar results, our analytical approach towards such clinical heterogeneity was to use a more robust analysis, with a random-effects model as opposed to a fixed-effects model.

Visual inspection of the overlapping of the 95% CIs in the forest plots (FIGURES 3 AND 4) also suggested statistical heterogeneity. There were nonoverlapping 95% CIs in the forest plot comparing pain outcomes between Pilates and minimal intervention, with the outcomes from the Gladwell et al²⁰ study not being consistent with the other 2 studies. Similarly, the O'Brien et al²⁶ study stood alone as an effective intervention comparing disability outcomes between Pilates and minimal intervention. However, the results obtained from using both fixed- and random-effects models were identical and in agreement. As such, we decided that the existing statistical heterogeneity was not so severe as to preclude pooling of data from the selected studies. Finally, the small sample sizes, dearth of studies, and poor methodological quality of some studies limited overall conclusions, which highlights the need for further research.

CONCLUSION

PILATES-BASED EXERCISES ARE SUPERIOR to minimal intervention for reduction of pain in individuals with nonspecific low back pain. However, Pilates-based exercises are no more effective than other forms of exercise to reduce pain. In addition, Pilates exercises are no more effective than minimal intervention or other exercise interventions to reduce disability related to chronic low back pain. However, the relatively low quality of existing studies and the heterogeneity of pooled studies in this systematic review combine to suggest that these results should be interpreted with caution. To have a more accurate representation of the extent of pain or disability reduction in such musculoskeletal pain condition, studies with better methodological qualities are needed. There is a clear need for well-designed randomized controlled trials with adequate follow-up to examine the effect of Pilates-based exercises for low back pain. Trials should also be adequately powered and intention-to-treat analysis should be performed to address dropout rates. Compliance of patients towards Pilates-based exercises should also be monitored. ●

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APPENDIX A

SEARCH STRATEGY FOR MEDLINE (PUBMED)

Limits applied: "Humans" and "English"

<ol style="list-style-type: none"> 1. Low back pain/ 2. LBP/ 3. Low back ache/ 4. Back pain/ 5. Backache/ 6. Spine pain/ 7. 1 or 2 or 3 or 4 or 5 or 6 8. Pilates/ 9. Exercise therapy/ 10. 8 or 9 	<ol style="list-style-type: none"> 11. 7 and 10 12. Randomised controlled trial/ 13. Controlled clinical trial/ 14. Clinical controlled trial/ 15. 12 or 13 or 24 16. 11 and 15
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APPENDIX B

THE DELPHI LIST⁴⁸

1. Treatment allocation	
a. Was a method of randomization performed?	Yes/No/Unsure
b. Was the treatment allocation concealed?	Yes/No/Unsure
2. Were the groups similar at baseline regarding the most important prognostic indicators?	Yes/No/Unsure
3. Were the eligibility criteria specified?	Yes/No/Unsure
4. Was the outcome assessor blinded?	Yes/No/Unsure
5. Was the care provider blinded?	Yes/No/Unsure
6. Was the patient blinded?	Yes/No/Unsure
7. Were point estimates and measures of variability presented for the primary outcome measures?	Yes/No/Unsure
8. Did the analysis include an intention-to-treat analysis?	Yes/No/Unsure

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