SYSTEMATIC REVIEW

A Systematic Review of the Effects of Pilates Method of Exercise in Healthy People

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ABSTRACT. Cruz-Ferreira A, Fernandes J, Laranjo L, Bernardo LM, Silva A. A systematic review of the effects of Pilates method of exercise in healthy people. Arch Phys Med Rehabil 2011;92:2071-81.

Objective: To evaluate evidence for the effectiveness of the Pilates method of exercise (PME) in healthy people.

Data Sources: Published research was identified by searching Science Direct, MEDLINE, PubMed, SPORTDiscus, PEDro, Cochrane Central Register of Controlled Trials, CINAHL, and Web of Science.

Study Selection: Research studies published from inception to May 7, 2011 were selected for evaluation. Two reviewers independently applied the inclusion criteria to selected potential studies. Studies were included if they were published in a peer-reviewed journal, written in the English language, conducted as a randomized controlled trial (RCT) or quasi-RCT in healthy people, had an inactive and/or exercise control group(s), included key study outcomes, and used the PME as the study intervention in at least 1 study arm.

Data Extraction: Two reviewers independently extracted data (study, design, subjects, intervention, key outcomes results), applied the Physiotherapy Evidence Database (PEDro) scale to assess the method quality of selected studies, and determined the strength of the evidence using the best evidence synthesis grading system.

Data Synthesis: Sixteen studies met the inclusion criteria. PEDro scale values ranged from 3 to 7 (mean, 4.1), indicating a low level of scientific rigor. The outcomes studied most often were flexibility, muscular endurance, strength, and postural alignment. The PME appears to be effective in improving flexibility (strong evidence), dynamic balance (strong evidence), and muscular endurance (moderate evidence) in healthy people.

Conclusions: There was strong evidence to support the use of the PME at least to the end of training to improve flexibility and dynamic balance and moderate evidence to enhance muscular endurance. Future RCTs should focus on the components of blinding, concealed allocation, subject adherence, intention-to-treat analysis, and follow-up designs.

Key Words: Pilates training; Rehabilitation; Studies method; Systematic review.

THE PILATES METHOD was created by Joseph Pilates, who combined exercise/movement, philosophy, gymnastics, martial arts, yoga, and dance into an approach for healthy living. This program of mind-body exercise is based on 6 key principles: centering, concentration, control, precision, flow, and breath.[1] According to Pilates, his method is total coordination of body, mind, and spirit, promoting the uniform development of the body; restoration of good posture and physical activity; and revitalization of the mind and spirit.[2] The Pilates method of exercise (PME) is practiced on a mat or Pilates apparatus (body conditioning equipment) in private lessons or small groups. Instructors are certified in the PME through any number of recognized Pilates certification programs.

Initially, the PME found great acceptance among professional dancers.[3] Today, the PME is popular in the general population[1,4,5] and the clinical and fitness areas.[3,5,6] This proliferation has led health and fitness professionals to question the scientific validity of the benefits espoused by Pilates himself. Bernardo[4] and Bernardo and Nagle[7] conducted critical appraisals of the published research in which the PME was tested in healthy adults and dancers, respectively. Their appraisals found weak support for the effectiveness of the PME on outcomes such as strength, flexibility, and alignment because of the quality of research methods and small sample sizes. A similar appraisal of the PME in healthy adults and dancers was conducted by Shedden and Kravitz,[8] who reinforced the necessity of well-controlled and well-designed studies to scientifically validate the effects of the PME in these populations.

Three systematic reviews[6,9,10] have been published on the effectiveness of the PME in relieving pain and improving function in adults with low back pain. La Touche et al[6] concluded that when adapted for subjects' situations, the PME improved general functioning and decreased pain. Conversely, Lim et al[9] found that although the PME is superior to minimal intervention, it is no more effective than other forms of exercise to reduce pain and disability. Posadzki et al[10] reported inconclusive evidence to support the clinical effectiveness of the PME in reducing pain and functional disability.

We conducted a systematic review to update the state of the science on effects of the PME in healthy people. The purpose of this systematic review was to answer the question: What is the evidence for the effectiveness of the PME in healthy people?

List of Abbreviations

BES	best evidence synthesis
PEDro	Physiotherapy Evidence Database
PME	Pilates method of exercise
RCT	randomized controlled trial

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METHODS

Search Strategy

Studies were selected for review on May 7, 2011, by searching the following databases: Science Direct, MEDLINE Cambridge (1997 to present), PubMed (1950 to present), MEDLINE EBSCOhost (1965 to present), MEDLINE (1950 to present), MEDLINE ISI Web of Knowledge (1950 to present), PEDro (1929 to present), Cochrane Central Register of Controlled Trials, SPORTDiscus (1800 to present), CINAHL (1937 to present), and Web of Science (1900 to present). The search term was *Pilates*, as found in the title or abstract.

Selection Criteria

Studies were included if they were published in a peer-reviewed journal, written in the English language, conducted as a randomized controlled trial (RCT) or quasi-RCT in healthy people, had an inactive control group and/or exercise control group(s), included key study outcomes (primary measures of the effectiveness or lack of effectiveness of the PME), and used the PME as the study intervention in at least 1 study arm.

Study Selection

Two reviewers (A.C.-F., L.L.) independently read all abstracts and classified them as excluded or potentially included. A third reviewer (J.F.) was consulted if there was disagreement between the 2 reviewers. Reviewers applied the inclusion criteria after reading the potentially included studies.

Data Extraction

Studies meeting the inclusion criteria were analyzed independently by the 2 reviewers to extract the following data: authors, year of publication, study design, subjects, intervention used, and key outcomes results. The third reviewer was consulted to resolve disagreements between the 2 reviewers.

Method Quality Assessment

The 2 reviewers independently assessed the method quality of each RCT by using the Physiotherapy Evidence Database (PEDro) scale,[11] with the third reviewer consulted to resolve disagreements. All RCTs were scored and entered into a spreadsheet (table 1).

The PEDro scale is based on a Delphi list developed by Verhagen et al[28] that includes 11 items: specified eligibility criteria, random allocation, concealed allocation, baseline comparability, blinded subjects, blinded therapists, blinded assessors, adequate follow-up, intention-to-treat analysis, between-group comparisons, and point estimates and variability. The eligibility criterion is related to external validity and is not used to calculate the PEDro score. PEDro scale scores range from 1 to 10; higher PEDro scores correspond to higher method quality. Because we do not know of the published validated cutoff scores for the PEDro scale, the following criteria were used to rate method quality: PEDro score of less than 5 indicates low quality and PEDro score of 5 or higher indicates high quality. The reliability of the PEDro scale has been evaluated previously and found sufficient for use in a systematic review of physical therapy RCTs[29] and appears to be a useful scale to assess the method quality of physical therapy trials.[30]

Data Synthesis

RCTs were divided into 2 groups, in which the PME group was compared with an inactive/usual exercise group or another exercise method. Outcomes were categorized as physiologic functioning, psychological functioning, and motor learning.[3]

Table 1: PEDro Scale Ratings

Study	Eligibility Criteria	Random Allocation	Concealed Allocation	Groups Similar At Baseline	Blind Subject	Blind Therapist	Blind Assessor	Follow-Up	Intention-to-Treat Analysis	Between-Group Comparisons	Point Measures and Variability	PEDro Score
Fitt et al, 1993[12]	1	1	0	0	0	0	0	1	1	0	0	3
Parrott, 1993[13]	0	0	0	0	0	0	0	1	1	0	1	3
McMillan et al,1998[14]	0	0	0	1	0	0	0	0	0	1	1	3
Jago et al, 2006[15]	0	0	0	1	0	0	0	1	1	1	1	5
Donahoe-Fillmore et al, 2007[16]	0	1	0	1	0	0	0	1	0	0	0	3
Johnson et al, 2007[17]	0	1	0	1	0	0	1	0	0	1	1	5
Sekendiz et al, 2007[18]	1	1	0	1	0	0	0	0	0	1	1	4
Caldwell et al, 2009[19]	0	0	0	1	0	0	0	0	0	1	1	3
Rogers and Gibson, 2009[20]	0	0	0	1	0	1	0	0	0	1	1	4
Caldwell et al, 2010[21]	0	0	0	1	0	0	0	0	0	1	1	3
Emery et al, 2009[22]	0	0	0	1	0	0	0	0	0	1	1	3
Kloubec, 2010[23]	0	1	0	1	0	0	0	1	0	1	1	5
Rodrigues et al, 2010[24]	0	1	0	1	0	0	0	0	0	1	1	4
Critchley et al, 2011[25]	1	1	1	1	0	0	1	0	0	1	1	6
Cruz-Ferreira et al, 2011[26]	1	1	1	1	0	0	1	0	1	1	1	7
Irez et al, 2011[27]	1	1	0	1	0	0	1	0	0	1	1	5
Total	5	9	2	13	0	1	4	5	4	13	13	

The strength of the scientific evidence was measured by using the best evidence synthesis (BES). BES is an alternative to meta-analysis when the number of eligible studies is too small to establish adequate power. BES has been used successfully by other reviewers,[31-34] including the Cochrane Back Review Group.[35] The strength is determined by the number and quality of studies and consistency of results. In this method, quality is more important than quantity.[35]

The following criteria are used to grade the strength of the evidence: strong evidence, provided in multiple high-quality RCTs; moderate evidence, provided in 1 high-quality RCT and 1 or more low-quality RCT; limited evidence, provided in 1 high-quality or multiple low-quality RCTs; and no evidence, provided in 1 low-quality RCT or contradictory outcomes.[36]

RESULTS

Study Selection

Figure 1 shows the flowchart of the article selection process. Thirty-one published reports were selected as potentially included for this review. Based on the reviewers' decisions, 16 RCTs matched the inclusion criteria. Seven articles were identified from the Science Direct database, with the remaining articles from MEDLINE (n=1), PubMed (n=3), Sportdiscus (n=3), CINAHL (n=1), and Web of Science (n=1).

Method Quality

PEDro scale scores ranged from 3 to 7 (mean, 4.1; median, 4; mode, 3). Most studies (n=10) scored less than 5,[12-14,16,18-22,24] and the rest (n=6) scored 5 or higher,[15,17,23,25-27] indicating a low and high quality of rigor, respectively. These 6 studies were published within the past 5 years (see table 1). The criteria satisfied most often related to statistical issues, such as the "similarity of the groups at baseline are reported for at least 1 key outcome," "results of between-group statistical comparisons are reported for at least 1 key outcome," and the "study provides both point measures and measures of variability for at least 1 key outcome." The criterion "blinded subject" was not satisfied in any RCT, with only 1 and 2 studies satisfying the criteria "blinded therapists" and "allocation was concealed," respectively (see table 1).

Study Characteristics

The most frequent study design was pre-post test (n=13), with 3 studies using an additional measurement during the study intervention.[19,21,26] None of the studies included follow-up. Sample sizes were small, ranging from 10 to 62, except in the studies by Caldwell et al,[19,21] in which 98 and 166 subjects were enrolled, respectively. Half (n=8) of the studies were conducted in adults[16-18,20,22,23,25,26]; 3 in dancers[12-14]; 3 in students[15,19,21]; and 2 in older adults.[24,27] Most RCTs enrolled both women and men (n=8),[12,17,19-23,25] with 7 studies limited to women[13,15 16,18,24,26,27] and 1 study that did not specify subject sex.[14] All studies used the PME as the study intervention. Control groups were inactive in 11 studies.[12,14,15,17,18,20,22-24,26,27] In the remaining 5 studies, the PME was compared with Taiji quan,[19,21] GYROKINESIS,[21] aerobic conditioning,[13] recreation,[19] general postural education,[16] and strength training.[25] The duration and frequency of PME interventions ranged from 5 to 15 weeks and 1 to 5 times per week, except for the study by Cruz-Ferreira,[26] which was conducted twice weekly for 6 months. Nine of the Pilates method interventions were performed on the mat,[15,16,18-20,23,25-27] with the rest performed on the apparatus (reformer, trapeze table, cadillac, wall unit, combo chair; n=2),[17,24] the mat and apparatus (n=3),[12,14,22] or not specified (n=2)[13,21] (table 2).

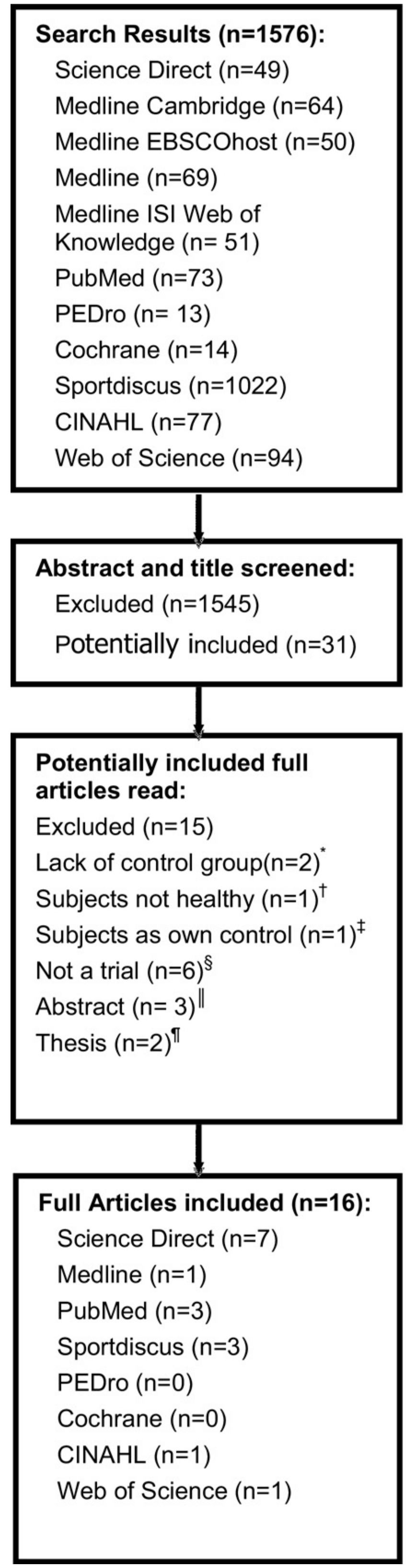

Fig 1. Flowchart of article selection process. *Segal et al,[5] Kaesler et al.[37] †Culligan et al.[38] ‡Kuo et al.[39] §Menacho et al,[40] Moreno,[41] Endleman and Critchley,[42] Herrington and Davies,[43] Petrofsky et al,[44] Queiroz et al.[45] ‖Sewright et al,[46] Otto et al,[47] Wu and Chiang.[48] ¶Hall,[49] Kish.[50]

Table 2: Description of Studies Included in RCT

Study	Design	Subjects	Intervention	Key Outcomes Results
Fitt et al, 1993[12]	Pre-post test Intervention period (phase I and phase II)	University dance students Phase I N=29; mean age, 21.21 Pilates group: n=14 Control group 1: n=15 Phase II Control group 2: n=8 (from Phase I control group 1)	Phase I Duration: 7wk Pilates group and control group 1 = habitual dance training (technique classes, rehearsals, and normal conditioning). Pilates group = habitual dance training and supervised Pilates session on mat (1 × 90′ per week) and individual work out on apparatus (2 × 30′ per week) and daily individual work out Pilates on mat. Phase II Duration: 5wk Control Ggoup 2 = unsupervised Pilates on mat and supervised Pilates on apparatus.	Phase I Pilates group = improved upper- and lower-limb strength, range of motion, and pelvic alignment; no differences on vertical jump. Control group 1 = no differences on most of the variables, improved on 2 strength variables, 1 range of motion variable and decreased on pelvic alignment. Phase II Control group 2 = improved strength, pelvic alignment, and 2 range of motion variables; no differences on vertical jump and 2 range of motion variables.
Parrott, 1993[13]	Pre-post test	Female university dance students N=18; age range, 9–30 Pilates group: n=6 Aerobic conditioning group: n=6 Control group: n=6	Duration: 14wk Pilates group, aerobic conditioning group, and control group = dance training (2–4h × 4 per week of rehearsal and 3–4h × 5 times per week of technique class - ballet, modern, and possibly jazz). Pilates group = dance training and Pilates class (3 × 80′ per week). Aerobic conditioning group = dance training and aerobic dance class (3 × 80′ per week).	Pilates group = improved standing and in-motion alignment, intention of movement and expressivity of the body. Aerobic conditioning group = improved the expressivity of the body. Control group = no differences.
McMillan et al,1998[14]	Pre-post test	Ballet dancers N=10; age range, 15–19 Pilates group: n=5 Control group: n=5	Duration: 14wk Pilates group = ballet training (20–25h/wk) and 23 private Pilates sessions (1h each). Pilates sessions on mat and apparatus. Control group = ballet training (20–25h/wk).	Pilates group = improved the dynamic alignment of the upper body region. Control group = no differences.
Jago et al, 2006[15]	Pre-post test	Female students N=30; mean age, 11.2 Pilates group: n=16 Control group: n=14	Duration and frequency: 4wk, 5 × 60′ per week. Pilates group = Pilates on mat. Control group = habitual exercise.	Pilates group = decreased body mass index percentile; no differences on body mass index, waist circumference, and blood pressure. Control group = no differences.
Donahoe-Fillmore et al, 2007[16]	Pre-post test	Healthy females N=11; age range, 25–35 Pilates group: n=6 Control group: n=5	Duration and frequency: 10wk Pilates group = general postural education (2 per week) and unsupervised Pilates on mat (3 per week). Control group = general postural education (2 per week).	Pilates group = improved flexor and extensor trunk endurance; no differences on abdominal strength and pelvic alignment. Control group = no differences.
Johnson et al, 2007[17]	Pre-post test	Healthy adults N=34 Pilates group: n=17; mean age, 27.5 Control group: n=17; mean age, 27.3	Duration: 10 sessions within 5wk. Pilates group = Pilates on apparatus. Control group = no exercise.	Pilates group = improved dynamic standing balance. Control group = no differences.

Table 2 (Cont'd): Description of Studies Included in RCT

Study	Design	Subjects	Intervention	Key Outcomes Results
Sekendiz et al, 2007[18]	Pre-post test	Sedentary adult females N=38 Pilates group: n=21; mean age, 30 Control group: n=17; mean age, 30	Duration and frequency: 5wk, 3 × 60′ per week. Pilates group = Pilates on mat Control group = no exercise.	Pilates group = increased abdominal and lower back strength, abdominal muscular endurance, and posterior trunk flexibility. Control group = no differences.
Caldwell et al, 2009[19]	Pre, mid, and post test	College-age individuals N=98 Pilates group: n=41 Taiji quan group: n=29 Recreation group: n=28 Mean age, 21.27	Duration: 15wk. Pilates group = 2 × 75′ per week or 3 × 50′ per week. Supervised Pilates sessions on mat. Taiji quan group = 2 × 50′ per week Taiji quan sessions. Recreation group = habitual exercise.	Pilates group = improved self-efficacy, positive mood, and sleep quality. Taiji quan = no differences. Recreation group = no differences.
Rogers and Gibson, 2009[20]	Pre-post test.	Healthy adults N=22 Pilates group: n=9; mean age, 25.5 Control group: n=13; mean age, 24.5	Duration and frequency: 8wk, 3 × 60′ per week. Pilates group = supervised Pilates sessions program on mat. Control group = habitual unsupervised, self-prescribed cardiovascular and strength training regimens.	Exercise group = improved body composition (body density, relative body fat, chest, waist, and arm circumference), flexibility (low back, hamstrings, and upper body), and muscular endurance (abdominal and lower back); no differences on hips and thigh circumference. Control group = no differences.
Caldwell et al, 2010[21]	Pre, mid, and post test	College students N=166 Pilates group: n=80 GYROKINESIS group: n=48 Taiji quan group: n=38	Duration: 15wk Pilates group and GYROKINESIS group=2 × 75′ or 3 × 50′ per week. Taiji quan group = 2 × 50′ per week.	Pilates, GYROKINESIS, and Taiji quan group = improved overall mindfulness. These increases were related with improved sleep quality, self-regulatory, self-efficacy, mood, and perception of stress.
Emery et al, 2009[22]	Pre-post test	Healthy adults N=19 Pilates group: n=10; mean age, 31.1 Control group: n=9; mean age, 28.6	Duration and frequency: 12wk, 2 × 60′ per week. Pilates group = private Pilates sessions on mat and apparatus. Control group = no exercise.	Pilates group = improved abdominal strength, thoracic kyphosis, and stabilization of core posture during shoulder flexion task movements. Control group = no differences.
Koulbec 2010[23]	Pre-post test	Healthy active middle age N=50; age range, 25–65 Pilates group: n=25 Control group: n=25	Duration: 12wk. Pilates group = 2 × 60′ per week. Supervised Pilates classes on mat. Control group = no exercise.	Pilates group = improved abdominal and upper body endurance and hamstring flexibility; no differences on static balance and posture. Control group = no differences.
Rodrigues et al, 2010[24]	Pre-post test	Elderly females N=52; mean age, 66 Pilates group: n=27 Control group: n=25	Duration and frequency: 8wk, 2 × 60′ per week. Pilates group = supervised Pilates on apparatus. Control group = no exercise.	Pilates group = improved the static balance, personal autonomy and quality of life index. Control group = no differences.

Table 2 (Cont'd): Description of Studies Included in RCT

Study	Design	Subjects	Intervention	Key Outcomes Results
Critchley et al, 2011[25]	Pre-post test	Healthy adults N=28; mean age, 30 Pilates group: n=17 Control group: n=11	Duration and frequency: 8wk, 2 × 45′ per week. Pilates group = unsupervised Pilates on mat. Strength group = unsupervised strength program.	Pilates group = improved transversus abdominis and decreased obliquos internus thickness when performing Pilates exercises; no differences in transversus abdominis and obliquos internus thickness at rest and during functional postures. Strength group = no differences.
Cruz-Ferreira et al, 2011[26]	Pre, mid, and post test	Adult females N=62; mean age, 41.08 Pilates group: n=38 Control group: n=24	Duration and frequency: 6mo, 2 × 60′ per week. Pilates group = supervised Pilates on mat. Control group = no exercise.	Pilates group = improved life satisfaction, physical self-concept, and perception of health status. Control group = no differences.
Irez et al, 2011[27]	Pre-post test	Elderly females N=60; aged ≤60y Pilates group: n=30 Control group: n=22	Duration and frequency: 12wk, 3 × 60′ per week. Pilates group = supervised Pilates on mat. Control group = no exercise.	Pilates group = improved strength, flexibility (hamstrings and lower back), dynamic balance, reaction time, and number of falls. Control group = no differences.

Effects of the PME on Health Outcomes

In physiologic functioning, improvements were reported in flexibility,[18,20,23,27] muscular endurance,[16,18,20,23] transversus abdominis thickness,[25] range of motion,[12] strength,[12,18,22,27] reaction time, number of falls,[27] and body composition.[15,20] No improvements were reported in transversus abdominis and obliquus internus thickness at rest or during functional postures,[25] blood pressure,[15] abdominal strength,[16] body composition,[15,20] and vertical jump.[12] In psychological functioning, improvements were found in intention of movement, expressivity of the body,[13] self-efficacy, positive mood and sleep quality,[19] mindfulness,[21] personal autonomy, quality-of-life index,[24] life satisfaction, physical self-concept, and perception of health status.[26] In motor learning, enhancements were observed in dynamic balance,[17,27] static balance,[24] stabilization of core posture,[22] and postural alignment.[12-14,22] No enhancements were found in postural alignment[16,23] or static balance.[23] Overall, the outcomes studied most often were flexibility,[18,20,23,27] muscular endurance,[16,18,20,23] strength,[12,16,18,22,27] and postural alignment[12-14,16,22,23] (see table 2).

Strength of the Evidence Using the BES Grading System

Applying the BES to measure the strength of the evidence, strong evidence was found for improving flexibility (physiologic functioning category)[18,20,23,27] and dynamic balance (motor learning category).[17,27] Moderate evidence was found for improving muscular endurance (physiologic functioning category).[16,18,20,23] Limited and no evidence was found for the rest of the outcomes. Table 3 lists the strength of the evidence of each outcome and the direction of the effect against a comparison group. Figure 2 shows the number of outcomes in each level of the strength of evidence. Contradictory results were found in a number of studies and are listed in table 4.

DISCUSSION

This systematic review was conducted to answer the question: What is the evidence for the effectiveness of the PME on outcomes in healthy people? This investigation adds to previous reviews by applying a method quality scale, evaluating the strength of evidence by using an established grading system, and including a larger number of published RCTs. We found strong evidence to support the use of the PME to improve flexibility and dynamic balance, moderate evidence to improve muscular endurance, and limited evidence to improve transversus abdominis and to decrease obliquus internus thickness during performance of the PME, and to improve reaction of time, number of falls, life satisfaction, physical self-concept, and perception of health status. Limited evidence was found, with no change in transversus abdominis and obliquus internus thickness while at rest or during functional postures. No evidence was found for the rest of the outcomes.

Until the mid-1980s, the PME was known and practiced almost exclusively by dancers. By the 1990s, this method had increased in popularity outside the world of dance.[1] This historical timeline helps explain why the first 3 RCTs, published in the 1990s, were conducted with dancers. Since 2000, with the proliferation of the PME into mainstream fitness and exercise, an increasing number of published RCTs using the PME in healthy people have been published. More than half (n=9) the published studies were performed on the mat compared with the apparatus and mat plus apparatus. This is not surprising because mat exercises are not as demanding in terms of supervision, are more affordable and readily available, and can be taught in larger groups

Table 3: Levels of Evidence of Outcomes in Physiologic, Psychological, and Motor Learning Categories

	Level of Evidence	Outcome	Study Arms
Physiologic Functioning Category	Strong evidence	Flexibility +	Compared with inactive control or habitual exercise groups.
	Moderate evidence	Muscular endurance +	
	Limited evidence	Transversus abdominis thickness when performing Pilates exercises +	Compared with strength group.
		Transversus abdominis and obliquos internus thickness at rest and during functional postures −	
		Reaction time +	Compared with inactive control group.
		Number of falls +	
	No evidence	Range of motion +	Compared with habitual exercise group.
		Strength + −	Compared with inactive control or habitual exercise group or general postural education group.
		Body composition + −	Compared with habitual exercise group.
		Vertical jump −	
Psychological Functioning Category	Limited evidence	Life satisfaction +	Compared with inactive control group.
		Physical self-concept +	
		Perception of health status +	
	No evidence	Intention of movement +	Compared with aerobic conditioning and inactive control groups.
		Expressivity the body +	
		Self efficacy +	
		Positive mood +	Compared with Taiji quan and habitual exercise groups.
		Sleep quality +	
		Mindfulness +	Compared with Taiji quan and Gyrokinesis groups.
		Personal autonomy +	Compared with inactive control group.
		Quality of life index +	
Motor Learning Category	Strong evidence	Dynamic balance +	Compared with inactive control group.
		Stabilization of core posture +	
	No evidence	Postural alignment + −	Compared with inactive control or habitual exercise groups or general postural education or inactive control group and aerobic conditioning groups or
		Static balance + −	Compared with inactive control groups.

Abbreviations: +, positive results; −, no changes; + −, contradictory results.

compared with apparatus exercises. There were no published studies comparing the type of Pilates training (mat or apparatus) and the type of Pilates certification method and its impact on outcomes.

The method quality of studies generally was low (mean score, 4.1). PEDro scale items satisfied most often in the 16 RCTs are related to the similarity of subject characteristics at baseline, between-group comparisons, and point measures and variability. These items indicate strengths in the subject enrollment process and in analyzing subjects' data by using meaningful measures and statistical analyses. Although all studies were reported as RCTs, 9 did not satisfy the randomization criteria because they did not explicitly state that allocation was random. Items less satisfied were criteria related to blinding (blinding of therapist and subjects) and random allocation. Blinding of subjects[31,51] and therapists[31] is difficult to achieve in exercise studies. The intention-to-treat criterion was satisfied in only 4 studies. This criterion is important when determining a study's power to detect differences between groups and can be a threat to external validity. Intention to treat also encompasses subject dropouts, and less than one-third of the studies had a dropout rate less than 15%. Exercise studies with control groups can be plagued with high dropout rates because of subject disinterest, and methods to retain randomly assigned subjects should be used.

Strong evidence was found for the PME improving flexibility compared with inactive[18,23,27] or habitual exercise groups[20] and dynamic balance compared with inactive groups.[17,27] This evidence was provided by 2 high-quality RCTs for each outcome.

Moderate evidence was observed for improving muscular endurance compared with inactive[18,23] or habitual exercise[20] or general postural education groups,[16] provided by 1 high-quality and 3 low-quality RCTs. Additionally, changes in muscular endurance were not observed in general postural education groups, which determines the superiority of PME enhancing this outcome.

Limited evidence was found in improving transversus abdominis and decreasing obliquos internus thickness of adults during performance of the PME by comparing the PME and strength training.[25] Neither group improved this outcome while at rest or during functional postures. Therefore, although the PME increased muscle mass, it did not improve function compared with strength training alone. Furthermore, limited evidence was found for improving reaction time, number of falls,[27] life satisfaction, physical self-concept, and perception of health status[26] when the PME was compared with an inactive control group.[26,27] These conclusions were drawn from 1 RCT with a high methodological quality.

There was no evidence for range of motion and vertical jump compared with a habitual exercise group.[12] No evidence was found for most outcomes of the psychological category. Women dance students who enrolled in Pilates method

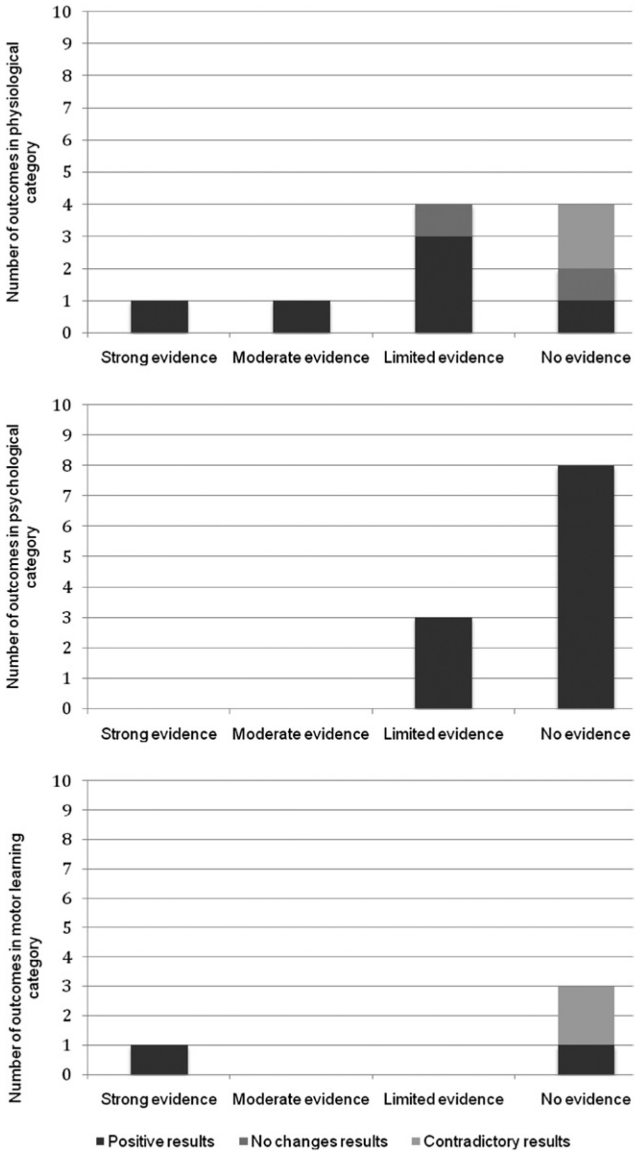

Fig 2. Number of outcomes in each level of strength evidence.

classes enhanced their intention of movement and expressivity of the body.[13] Although the control group had no differences, the aerobic conditioning group improved only expressivity of the body, which does not establish the superiority of the PME in this outcome. Similar conclusions were presented by Caldwell et al,[21] in which mindfulness was reported in college students after practicing the PME, GYROKINESIS, and Taiji quan programs. All these interventions are mind-body fitness methods; therefore, variability among groups was expected to be minimal. In contrast, Caldwell et al[19] showed that the PME promoted self-efficacy, positive mood, and sleep quality, making this method a better choice than Taiji quan and recreation. These health outcomes are psychological in nature, and the physicality of the PME may contribute to the improved outcomes in this study.

No evidence was found for outcomes with contradictory results, which calls into question the effectiveness of the PME in outcomes in the physiologic (body composition and strength) and motor learning (postural alignment, static balance) categories (see table 4). Contradictory results were found for abdominal strength, for which improvements were observed by Sekendiz,[18] Emery,[22] and colleagues and no improvements were found by Donahoe-Fillmore et al.[16] Differences between Sekendiz,[18] Donahoe-Fillmore,[16] and colleagues may be related to the process for measuring abdominal strength (maximum curl-ups vs isometric contraction, respectively). Contradictions with conclusions drawn by Emery,[22] Donahoe-Fillmore,[16] and colleagues may be due to the instructional and Pilates equipment methods (private Pilates method on the mat and apparatus vs unsupervised Pilates method on the mat, respectively) and duration of the Pilates method intervention (12 vs 10wk, respectively). In the study by Jago et al,[15] no differences were found in women students' waist circumferences after 4 weeks of practicing the PME on the mat. Alternatively, Rogers and Gibson[20] found improvements in waist circumference after 8 weeks of practicing the PME. Knowing that the procedure for waist measurement was the same for both studies, the difference in waist measurements may be because of the duration of the intervention, for which 4 weeks was not sufficient to produce decreases in waist circumference. Donahoe-Fillmore,[16] Fitt,[12] and colleagues assessed pelvic postural alignment by using the same procedures. In the first study, 10 weeks of general postural education and unsupervised Pilates on the mat did not produce effects on pelvic alignment in healthy adult women[16] compared with the general postural education group. In comparison, dance students, after 7 weeks of habitual dance training, supervised Pilates method on the mat, individual work on the apparatus, and daily individual work with Pilates on the mat, improved pelvic postural alignment.[12] The dancers' workload and supervised training could explain the differences in findings. Furthermore, dance students have an inherent capacity to internalize and apply the PME in their body work. Benefits were found in static balance in Rodrigues et al's investigation,[24] whereas Kloubec[23] did not observe differences. Such differences may be because of the measures devices and type of intervention. Rodrigues[24] used the Tinetti test,[52] and the intervention was based on supervised Pilates on the apparatus. Kloubec[23] used a balance board, and the intervention consisted of supervised Pilates on the mat. Thus, the contradictory findings may be because of differences in surface (stable vs unstable) and equipment (Pilates equipment vs the mat).

The low PEDro scale scores indicated weaknesses in research methods (lack of blinding, intention to treat, concealed allocation), and the lack of strength of evidence calls into question the effectiveness of the PME in healthy people and implies caution when applying the findings into practice. Other factors that affect the scientific validity of the effects include the type of certified PME, veracity of the PME instructor, and variability in measurement, study length, frequency of PME sessions, and age ranges of subjects.

Study Limitations

There are a number of limitations with our systematic review. We excluded all studies that were not RCTs or were quasi-RCTs. We did not determine the validity and reliability of the instruments, integrity of the type of PME taught, qualifications of Pilates method instructors, or appropriateness of statistical analyses. Outcomes were broadly grouped, and studies used various criteria for measuring outcomes. No study conducted follow-up assessments to determine lasting effects of the PME on outcomes. A meta-analysis of all RCTs was not feasible because of the clinical heterogeneity of study mea-

Table 4: Outcomes With Contradictory Results in Healthy People

	Outcome	Study	Results
Strength	Upper and lower limbs	Fitt et al, 1993[12]	Pilates group improved upper- and lower-limb strength when compared with habitual dance training group.
	Lower back	Sekendiz et al, 2007[18]	Pilates group improved lower back strength when compared with no exercise control group.
	Hip	Irez, et al, 2011[27]	Pilates group improved hip strength, when compared with no exercise control group
	Abdominal	Sekendiz et al, 2007[18] Emery et al, 2010[22]	Pilates group improved abdominal strength when compared with no exercise control group.
		Donahoe-Fillmore et al, 2007[16]	Pilates group did not improve abdominal strength when compared with general postural education group.
Body Composition	Body mass index percentile	Jago et al, 2006[15]	Pilates group improved body mass index percentile when compared with habitual exercise control group.
	Body mass index	Jago et al, 2006[15]	Pilates group did not improve body mass index when compared with habitual exercise control group.
	Waist circumference	Jago et al, 2006[15]	Pilates group did not improve waist circumference when compared with habitual exercise control group.
	Body density	Rogers and Gibson, 2009[20]	Pilates group improved body density when compared with habitual self-prescribed cardiovascular and strength training group.
	Relative body fat	Rogers and Gibson, 2009[20]	Pilates group improved relative body fat when compared with habitual self-prescribed cardiovascular and strength training group.
	Chest, waist, and arm circumference	Rogers and Gibson, 2009[20]	Pilates group improved chest, waist, and arm circumference when compared with habitual self-prescribed cardiovascular and strength training group.
	Hips and thigh circumference	Rogers and Gibson, 2009[20]	Pilates group did not improve hips and thigh circumference when compared with habitual self-prescribed cardiovascular and strength training group.
Balance	Static balance	Kloubec, 2010[23] Rodrigues et al, 2010[24]	Pilates did not improve static balance when compared with no exercise control group. Pilates improve static balance when compared with no exercise control group
Postural Alignment	Pelvic	Fitt et al, 1993[12]	Pilates group improved pelvic alignment when compared with habitual dance training group.
	Pelvic	Donahoe-Fillmore et al, 2007[16]	Pilates group did not improve pelvic alignment when compared with no general postural education group.
	Standing and in-motion alignment	Parrott, 1993[13]	Pilates group improved standing and in-motion alignment when compared with no exercise group and aerobic conditioning group.
	Dynamic	McMillan et al, 1998[14]	Pilates group improved dynamic alignment of upper body region when compared with habitual dance training group.
	Thoracic	Emery et al, 2009[22]	Pilates improved thoracic kyphosis when compared with no exercise control group.
	Unspecified	Kloubec, 2010[23]	Pilates did not improve posture when compared with no exercise control group.

sures, small sample sizes, and lack of randomization. PEDro scale scoring comes with it own biases because items were scored only when the study clearly reported that criteria were met. The BES is relatively new in its application; thus, the strength of the evidence may have been over- or underestimated.

Recommendations for Future Research

The method quality of RCTs involving the PME should be improved to minimize bias, namely, concealing group allocation, using blinding criteria, using power analysis to determine sample size, applying an intention-to-treat analysis, and using interventions to decrease dropout rates. Furthermore, reporting the type of PME, order of exercises, and number of repetitions for each exercise would allow for reproducibility and consistency among researchers. Maintaining consistency in study duration and number and length of PME sessions would enhance the translation research findings into practice.

CONCLUSIONS

Findings from this systematic review indicate that the PME in healthy people has a low quality of scientific rigor. There was strong evidence to support use of the PME, at least at the end of training, to improve flexibility and dynamic balance and moderate evidence to enhance muscular endurance. Given the paucity of published RCTs, lack of follow-up designs, low method quality of most RCTs, and limited strength of the evidence, more rigorous and robust methods should be used in future investigations.

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