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Pilates exercise and postural balance in older adults: A systematic review and meta-analysis of randomized controlled trials

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Pilates exercise and postural balance in older adults: A systematic review and meta-analysis of randomized controlled trials.

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Highlights

- Pilates training can induce favorable effects on postural balance.
- Pilates effects on the postural balance is not related to length of intervention.
- Pilates effects on the postural balance is not related to Pilates amount per week.
- Pilates effects on the postural balance is not related to study quality.

ABSTRACT

Introduction: The effects of exercising with the Pilates method on aspects such as balance for the general population have been reported by recent systematic reviews. However, whereas the effects of the Pilates method on improving general balance have been well studied, less is known about postural balance and the respective determinants of Pilates effects. **Objectives:** (1) provide more up-to-date evidence to determine the effects of Pilates on postural balance and (2) examine the effects of length of intervention, Pilates amount per week (times per week X session duration), and study quality (risk of bias) on postural balance in older adults. **Methods:** A systematic electronic search in Medline and Scientific Electronic Library Online (SciELO) was completed in December 2018 identifying randomized controlled trials investigating the effect of a Pilates method on postural balance in healthy older adults. A subsequent meta-analysis was performed. **Results:** The meta-analysis involved 6 studies and 261 individuals (128 Pilates and 133 control groups). We observed an overall effect favoring the Pilates group $SMD_{95\%}$=0.89 [0.29-1.49]. The subgroup mean effects were similar for "length of intervention" (low vs high) [*P*=0.557], "Pilates amount per week" (low vs high) [*P*=0.565], and "study quality" (low vs high) [*P*=0.869]. **Conclusion:** Accordingly, our findings suggest that a Pilates training program can be considered as an effective form of exercise to improve balance in older adults. Additionally, length of intervention, Pilates amount per week, and study quality were not related to the magnitude of effect on postural balance.

Keywords: Pilates training, postural balance, exercise movement techniques.

1. Introduction

The Pilates method (initially called *Contrology*), according to Joseph Pilates was designed to improve general body flexibility and health, focusing on enhancing core strength, posture, and coordination of breathing through movement[1]. The Pilates method is a unique approach to training in mind-body awareness and control of movement and posture. Specialized apparatus provides an opportunity to train a variety of movement patterns and postures[2]. Pilates has become a target of interest as a form of useful exercise in recent years[1], being based on 8 principles: control, breathing, flowing movement, precision, stability, centering, range of motion, and opposition[3].

It is important to highlight that balance limitations involve deficits in the proprioceptive system, with altered movement patterns and difficulties in walking and maintaining postural control, which consequently affect the performance of activities of daily living and quality of life[4], especially in the elderly. Balance disorders are among the most common causes of falls in older adults and often lead to injury, disability, loss of independence, and limitations[5]. For this reason, the effects of exercising with the Pilates method on aspects such as balance for the general population have been reported by recent systematic reviews[6-8].

In terms of balance, it is important to emphasize that balance is defined as a person's ability to control their body position within the limits of the base of support[9]. Balance can be categorized into postural balance (quiet erect standing) and dynamic balance (the capacity to maintain or regain a stable position of the body during movements or in response to a perturbation)[10]. Thus, balance as an umbrella term includes the combination of both the control of posture and the control of equilibrium. In this discrimination, postural control encompasses achieving and maintaining a desired body position in any static or dynamic situation. Equilibrium control encompasses maintaining the intersegmental stability of the body in spite of gravitational and inertial forces acting on it[11].

Considering these aspects, previous systematic reviews have included different "types of balance" in the same analysis. For this reason, it is important to advance the Pilates effects on postural control and equilibrium, focusing on the specific type of equilibrium. Additionally, previous studies do not include statistical approaches aimed at elucidating the possible determinants of the Pilates method on postural balance. Important variables, such as "length of intervention" and "Pilates amount per week" can influence the effect-size of the Pilates intervention. Risk of bias is another important factor that may influence the magnitude of treatment responses. Contemporary meta-analysis methodologies offer greater precision of point estimates, as well as enhanced statistical power, and may contribute to resolving uncertainty and answering questions that were not posed at the start of individual trials[12].

Therefore, this systematic review with meta-analysis aims to (1) provide more up-to-date evidence to determine the effects of Pilates on postural balance and (2) examine the effects of length of intervention, Pilates amount per week, and study quality (risk of bias) on postural balance in older adults.

2. Methods

2.1. Eligibility criteria

This systematic reviews with meta-analysis is registered in the International Prospective Register of Systematic Reviews (PROSPERO) trial registry (CRD42019128831). In addition and where applicable, the general guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) Statement[13] were followed.

Studies were included if the following criteria were fulfilled: (1) randomized controlled trials (RCTs), (2) in which the primary intervention being evaluated was the Pilates training method using either mats, equipment, or both, (3) for physically independent older adults with a mean age of 60 years or more, and with (4) no diagnosed pathology, (5) reporting postural balance for both the Pilates and control session/group, and with (6) postural balance evaluated by the body sway measurements.

The eligibility for the selection of the studies was determined through the PICOS process (Table 1).

Table 1. Criteria for inclusion and exclusion of studies selected for review.

		Inclusion Criteria	Exclusion Criteria
P	Population	Physically independent older adults with a mean age of 60 years or more.	Patients with musculoskeletal disorders/other chronic disease.
I	Intervention	Pilates training method using either mats, equipment, or both.	Massage, manual therapies, alternative therapies, Pilates combined with other interventions.
C	Comparison	With sedentary control.	-
O	Outcome	Postural balance (static) by body sway measurements.	Dynamic balance and studies that evaluated the postural balance by means of "functional tests" and "questionnaires".
S	Study type	Randomized Control Trial	Systematic review, cross-sectional, case reports, observational study, review, protocol study, qualitative study.

2.2. Database search

The online databases Medline and Scientific Electronic Library Online (SciELO) were searched from their inception until December 2018 by one author (JC) and checked by another author (CMY). Studies published in grey literature were not included. Search terms included a mix of Medical Subject Headings (MeSH-terms) and free-text words for key concepts related to Pilates exercise and postural balance. As an example, the full-search strategy for the PubMed database was: "(Exercise Movement Techniques [Mesh] OR Movement Techniques, Exercise [Title/Abstract] OR Exercise Movement Techniques [Title/Abstract] OR Pilates-Based Exercises [Title/Abstract] OR Exercises, Pilates-Based [Title/Abstract] OR Pilates Based Exercises [Title/Abstract] OR Pilates Training [Title/Abstract] OR Training, Pilates [Title/Abstract]) AND (Postural Balance [Mesh] OR Balance, Postural [Title/Abstract] OR Musculoskeletal Equilibrium [Title/Abstract] OR Equilibrium, Musculoskeletal [Title/Abstract] OR Postural Equilibrium [Title/Abstract] OR Equilibrium, Postural [Title/Abstract])". These were combined with a sensitive search strategy to identify RCT's. No language restrictions were applied during the search. All studies not meeting the previously mentioned criteria or duplicate publications were excluded.

The study selection process is summarized in Figure 1. In brief, 392 potentially relevant studies were retrieved and screened by reviewing the title and abstract. The six studies that were eligible for inclusion were then subjected to data extraction.

2.3. Study identification, data extraction, and quality assessment

The texts were screened first by title and abstract. Next, they were assessed for eligibility after an in-depth reading. Articles finally included were analyzed using the following structure: ID of the study, ID in PubMed or digital object identifier, author, year, study design, Pilates and control group interventions, and outcomes in terms of postural balance. A standardized and predefined Excel spreadsheet was used. Extracted study and subject data included, but were not limited to, variables related to publication details (first author, year, country of origin); study design, participant characteristics (gender, age, and number of participants in the trial); exercise characteristics (frequency, session duration, length of intervention); balance measurement (device/technique); study quality and outcome measures (mean, SD, SEM). A standardized coding form was used and information was archived in a database.

Two reviewers (JC, CMY) independently assessed the risk of bias for the included studies using the Cochrane Collaboration 'risk of bias' tool[14]. For each included study, the following items were evaluated: 1) selection bias; 2) performance bias; 3) detection bias; 4) attrition bias; 5) reporting bias; and 6) other sources of bias. Item selection bias includes an evaluation of randomization and allocation concealment; performance bias includes assessments about the blinding of participants and personnel; detection bias includes the blinding of outcome assessment; attrition bias evaluates the incomplete outcome data; and reporting bias assesses selective revealing or suppression of information[15]. This tool urges users to assign a judgment of "high", "low", or "unclear" to the risk of bias and to document the basis for their judgments[16]. The information was provided with the punctuation criteria and the motivation for their use. Kappa coefficients were calculated to assess agreement between the reviewers.

Disagreements were resolved by discussion. Studies were not excluded based on their quality.

2.4. Statistical Analysis

Analyses were performed using the Comprehensive Meta-Analysis software (CMA, version 2.2.064, Biostat, NJ, USA). Two-sided statistical significance was set at $P<0.05$. The primary outcome measure was an effect on postural balance. Descriptive data of treatment groups and participants are reported as mean ± SD. Study data were pooled using a random effects model. Comparisons for trials with more than one intervention were disaggregated. Effect sizes were calculated for each comparison and analyzed as separate studies. Inconsistencies were estimated using the I^2 statistic.

Additionally, we tested three a priori defined hypotheses that there might be differences in the effects of Pilates exercise on postural balance with regard to 1) length of intervention [<8 weeks (low) and ≥8 weeks (high)]; 2) Pilates amount per week [<150 minutes (low) and ≥150 minutes (high); 3) study quality (based on the Cochrane Collaboration risk of bias tool[14]) [≤3 points (low) and >3 points (high)]. Cutoff points were established based on central tendency measures (median), trying to approximate the 50th percentile value as much as possible. Differences between subgroups were analyzed by means of analysis of variance (Q-test based ANOVA). Funnel plot asymmetry to identify publication bias was evaluated through visual inspection of the funnel plots. In addition the Duval and Tweedie trim and fill computation was used to estimate the effect of publication bias on the results[17].

3. Results

3.1. Study Characteristics

As shown in Figure 1, six randomized controlled studies[18-23] were identified that fulfilled the inclusion criteria, involving 261 individuals (128 Pilates and 133 control groups). Participant characteristics, intervention, and postural balance effect are shown in Table 2. The studies were conducted between 2012 and 2017. Except for one study, all trials used a parallel-group design. Sample sizes ranged between 27 and 88 subjects. Participants ranged in age from 59 to 79 years. Two studies involved only women and four studies included both men and women.

Table 2. Participant characteristics, intervention, and postural balance effect.

Study	Subjects characteristics	Study design	Pilates intervention	Balance assessment	Outcome measures	Length of intervention	Pilates amount per week	Pilates total work	Postural balance effect
Bird et al.[18]	27 (21 women/6 men) participants, 67±6 years.	Crossover RCT	2 times per week/60min + 1 (home/60min), PM and PA (Reformer and trapeze)	Force platform	CoPx	5 weeks	180	900	↑ postural balance
Donath et al.[19]	48 (36 women/12 men) participants, 69±6 years.	Parallel-group RCT	2 times per week/60min, PM (in supine position, prone plank, quadruped or sitting position).	Force platform	CoPy	8 weeks	120	960	NS
Gabizon et al.[20]	88 (45 women/43 men) participants, 71±4 years.	Parallel-group RCT	3 times per week/60min, PM (with Thera-band & Pilates ball)	Force platform	CoP area	12 weeks	180	2160	NS
Hyun et al.[21]	40 (40 women/0 men) participants, 70±2 years.	Parallel-group RCT	3 times per week/40min, PM	Force platform	CoP velocity	12 weeks	120	1140	↑ postural balance
Lopes et al.[22]	46 (27 women/19 men) participants, 70±2 years.	Parallel-group RCT	3 times per week/40min, PM	Force platform	CoP area	12 weeks	120	1440	↑ postural balance
Mesquita et al.[23]	58 (58 women/0 men) participants, 69±5 years.	Parallel-group RCT	1 time per week/20min, PM (with Pilates ball, Thera-band and magic circle)	Force platform	CoP area	acute	20	20	↑ postural balance

RCT = Randomized Clinical Trial; PM = Pilates Mat work; CoP – centre of pressure; CoPx = antero-posterior displacement of the centre of pressure; CoPy = medio-lateral displacement of the centre of pressure; Pilates amount per week = times per week X session duration (min); Pilates total work = times per week X session duration (min) X length of intervention.

3.2. Risk of bias within studies

Figure 2 shows the risk of bias for the included studies. Studies included were assessed as having a high or unclear risk of selection bias (random sequence generation [1/6] and allocation concealment [2/6]), detection bias (blinding of outcome assessment) [6/6], attrition bias (incomplete outcome data addressed) [2/6], and reporting bias (selective reporting) [2/6]. The kappa correlation showed a good overall agreement between the researchers (k= 0.853; 0.744–0.949 [95%CI]) $P<0.001$. All studies reported point and variability measures for postural balance; in all studies baseline postural balance was similar between control and intervention groups.

3.3. Risk of bias across studies

The potential for publication bias was assessed through visual inspection of the funnel plot (Figure 3). The Duval and Tweedie correction model[17] was applied to the Pilates study groups for postural balance. No trimmed studies could be identified.

3.4. Main outcomes

Figure 4 presents the forest plots for postural balance (standard mean difference [SMD]) after a Pilates training intervention. We observed an overall effect favoring the Pilates group ($SMD_{95\%}$=0.89 [0.29-1.49]). The raw mean differences (MD) grouped by outcome measures are presented in the Figure 5. Considering the centre of pressure (CoP) area, a significant overall effect ($MD_{95\%}$= 0.78 [0.05-1.52]) favoring the Pilates group was identified. The single study results for antero-posterior displacement of the centre of pressure (CoPx), medio-lateral displacement of the centre of pressure (CoPy), and CoP velocity are also presented.

The subgroup mean effects (table 3) were similar for "length of intervention" (low vs high) [*P*=0.557], "Pilates amount per week" (low vs high) [*P*=0.565], and "study quality" (low vs high) [*P*=0.869].

Table 3. Subgroup analyses for the effect of Pilates exercise on postural balance.

				Heterogeneity test		
	N	**ES (95% CI)**	***P* (interaction)**	**Q**	***P***	**I^2**
Length of intervention			0.557			
Low (<8 weeks)	2	0.71 (0.27;1.15)		0.12	0.721	0.0
High (≥8 weeks)	4	1.03 (0.05;2.01)		24.93	<0.001	87.9
Pilates amount per week			0.565			
Low (<150 min)	4	0.71 (0.29;1.13)		4.98	0.173	39.8
High (≥150 min)	2	1.48 (-1.10;4.08)		19.95	<0.001	94.9
Study quality			0.869			
Low (≤3 points)	3	0.87 (0.50;1.24)		1.82	0.401	0.0
High (>3 points)	3	0.98 (-0.33;2.30)		21.11	<0.001	90.5

N= number of trials; ES= effect size; Pilates amount per week = times per week X session duration (min).

4. Discussion

The major findings of this meta-analysis showed that Pilates training can induce favorable effects on postural balance, with a high practical effect in healthy older adults. Additionally, this favorable effect is not necessarily related to length of intervention, Pilates amount per week, or study quality. Human balance depends on coordinated integration of somatosensory, vestibular, and visual input[24]. Improvements in balance have been reported and explained based on different theories. Works such as that conducted by Bird et al.[18] proposed that changes occur in the central nervous system at the level of synaptic connections, with changes in the cortical map and muscle activation strategies. This was based on findings of a study where balance improvements persisted even after ceasing the activity, though strength in the lower limbs failed to do so, supporting the idea of neural adaptation.

To increase physical stability, trunk stabilization exercise is helpful for enhancing balance ability, as the muscular strength of the trunk, among other different factors, is related to balance and functional activities[25]. Activity of the trunk muscles maintains balance against gravity, adjusts posture, and prepares for the movement of the extremities in activities of daily living[26]. Several physical exercises to increase balance ability focus on trunk stabilization. Pilates exercises also stress strengthening of the muscles to stabilize the trunk through core exercise[27].

Previous studies have suggested that enhancement in the muscles involved in proprioception of the center of the body could stabilize posture and trunk alignment, releasing part of the load on the limbs and resulting in improved balance[23]. The resultant lower limb strengthening caused by the Pilates training program could also influence balance capabilities[28-30].

It is important to highlight that balance may be static when the body is either at rest (postural balance) or dynamic when the body is in steady-state motion (dynamic balance). Therefore, the present study only examined the effects of Pilates training on postural balance. Other systematic reviews have investigated the effects of Pilates training on dynamic balance[6-8]. To the best of our knowledge, this is the first systematic review with meta-analysis to investigate the effects of Pilates training specifically on postural balance, focusing only on studies that evaluated body sway measurements.

Another important aspect of originality is related to the subgroup analysis. Thus, the "length of intervention" (<8 weeks vs ≥8 weeks) was not related to the magnitude of effect on postural balance. Therefore, long Pilates training programs do not seem to be related to greater effects on postural balance. On the other hand, it is worth noting that the longest training programs lasted for only 12 weeks. In this sense, there is a lack of studies with a longer intervention period.

In the same way, the "Pilates amount per week" does not appear relevant to modulate the improvement in postural balance. Low (<150 min) and high (≥150 min) amount per week presented similar adaptations in postural balance. According to the reported effects, 150 min per week may be enough to produce positive effects in terms of balance among older adults. The minimum amount per week to produce improvement in postural balance was 20 min[23]. The results also suggested that "study quality", based on the Cochrane Collaboration risk of bias tool[14] is not related to postural balance improvement. Studies with "low" or "high" risk of bias demonstrated similar results.

Some limitations must be mentioned. First, there are a small number of studies, which limits the generalizability of the results. Furthermore, our meta-analysis showed a moderate degree of heterogeneity; however, since systematic reviews bring together studies that are both clinically and methodologically diverse, heterogeneity in the results is to be expected[31]. Next, in line with our previous meta-analyses and in order to allow for comparison with other meta-analyses in the field, we restricted the inclusion criteria to full publications in peer-reviewed journals as data from abstracts that remain unpublished may not be reliable and usually contain insufficient information; in addition, it is not possible to identify all relevant unpublished material[32]. However, we do acknowledge that because of this, our results might slightly overestimate the observed effect in the current meta-analysis. Namely, it has been shown that effect size estimates of published research are approximately a third larger than those of unpublished studies[32]. Yet, given that we did not find any signs of expressive asymmetry in the funnel plots, we believe that is it reasonable to assume that publication bias did not affect our results.

It is important to highlight that this systematic review provided quantitative data synthesis on the effect of Pilates specifically on postural balance. All the studies in this review offered a critical discussion of their findings, description of potential clinical impact and application, and contextualization within contemporary literature. Additionally, to provide a more tangible effect, this systematic review presented the raw mean difference results by the pooled effect of the studies that used the same outcome measure. It is important to highlighted that, while the evaluation of CoP excursions is a commonly used method for measuring postural stability[33], no standardization of this method exists.

5. Conclusion

Our findings suggest that Pilates training program can be considered as an effective form of exercise to improve balance in older adults. Additionally, length of intervention, Pilates amount per week, and study quality were not related to the magnitude of effect on postural balance.

CRediT Author Statement

J. Casonatto: Conceptualization, Methodology, Software, Formal Analysis, Writing-Review & Editing, Project Administration. C. Yamacita: Methodology, Software, Verification, Formal Analysis, Visualization.

Conflict of Interest

None.

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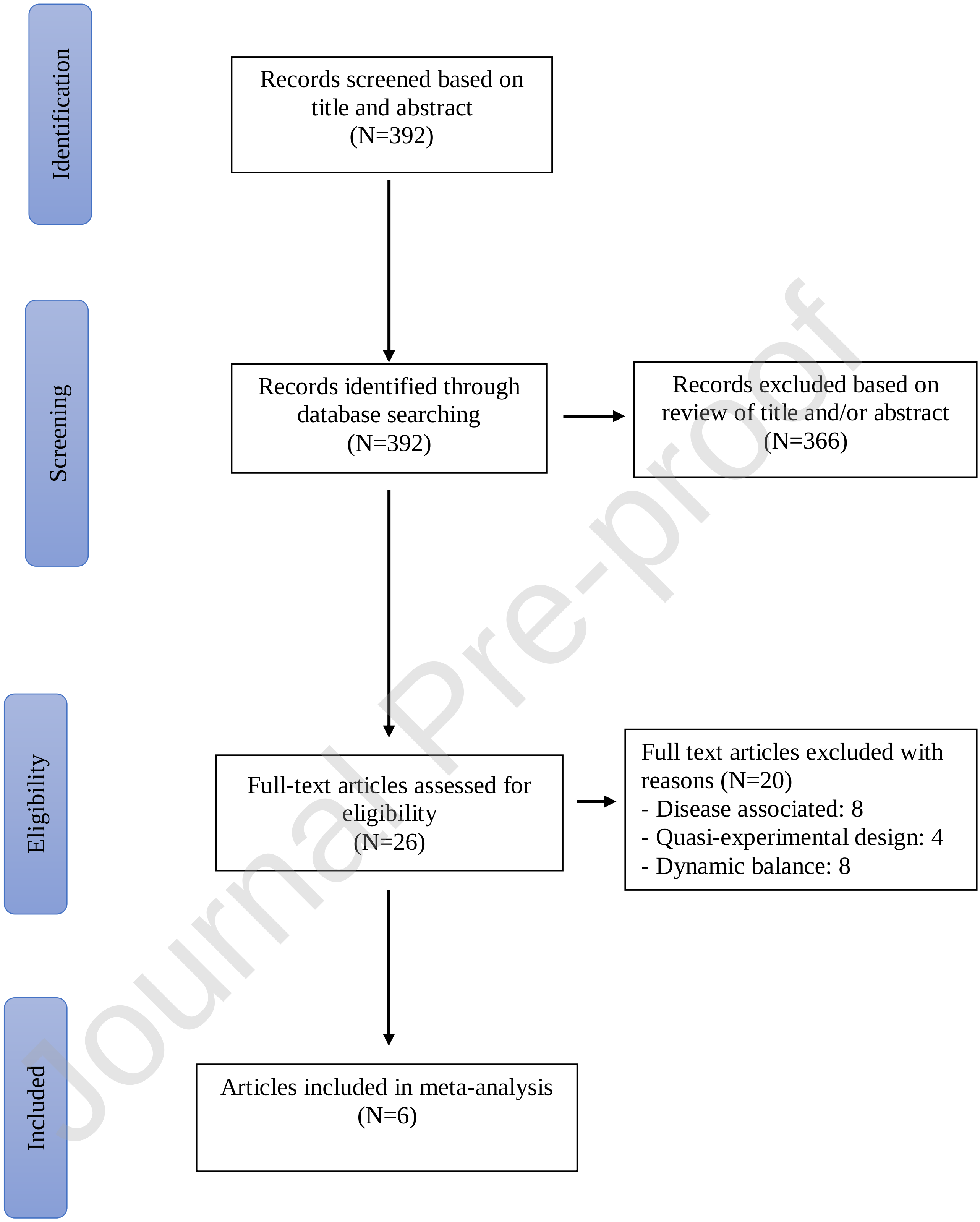

Figure 1. Flow chart.

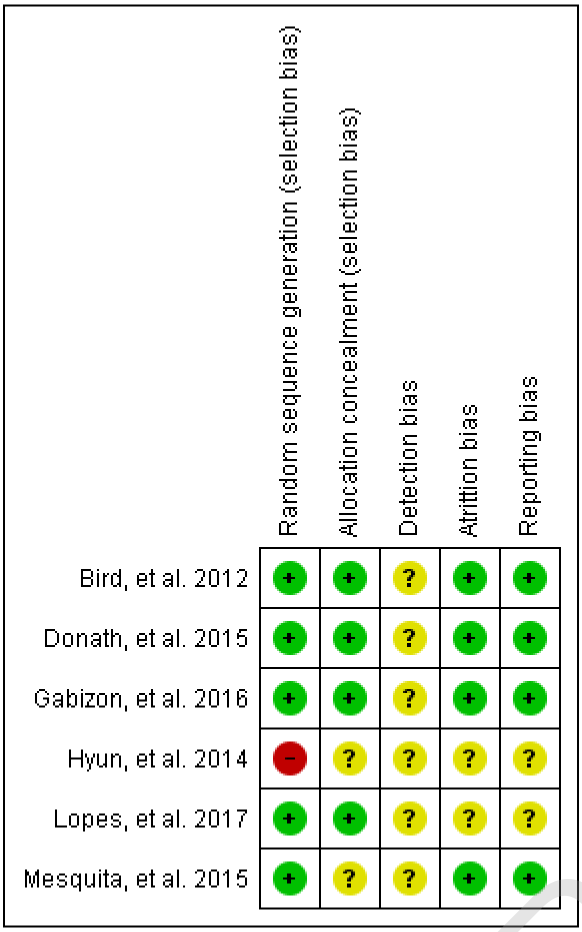

Figure 2. Quality of the studies included.

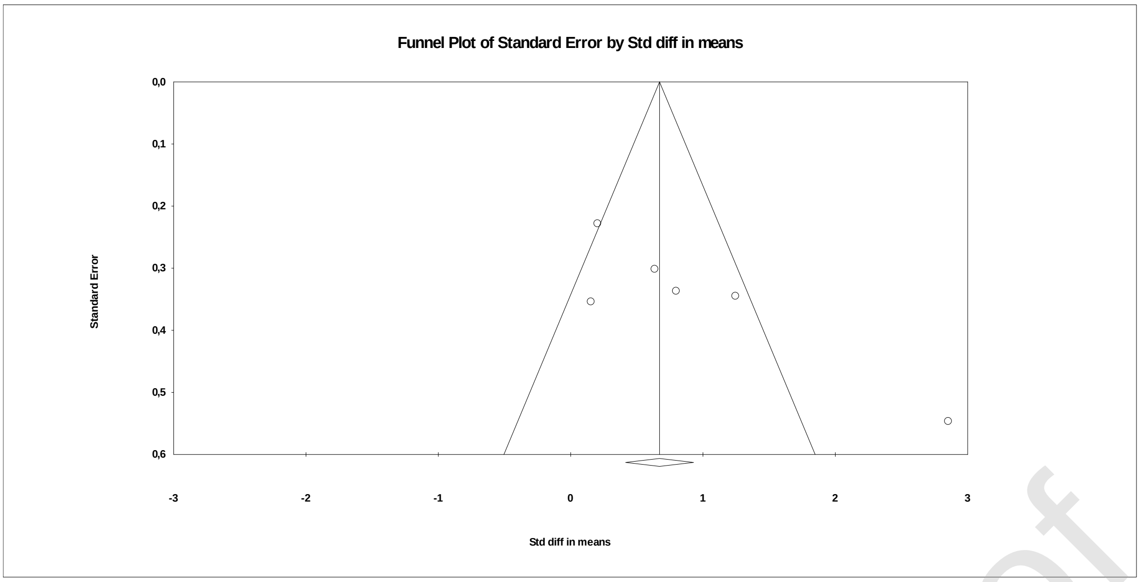

Figure 3. Funnel-plot.

Standard Mean Difference

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Lopes, et al. 2017	0,640	0,302	0,091	0,047	1,232	2,116	0,034
Gabizon, et al. 2016	0,208	0,229	0,052	-0,241	0,656	0,907	0,364
Mesquita, et al. 2015	0,802	0,338	0,114	0,140	1,464	2,375	0,018
Donath, et al. 2015	0,333	0,357	0,127	-0,366	1,032	0,935	0,350
Hyun, et al. 2014	1,250	0,346	0,120	0,572	1,928	3,616	0,000
Bird, et al. 2012	2,858	0,547	0,300	1,785	3,931	5,221	0,000
	0,914	0,298	0,089	0,330	1,498	3,069	0,002

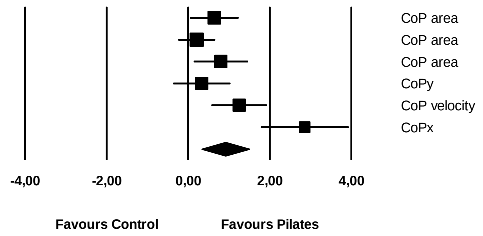

Figure 4. Effects of Pilates on postural balance (Standard mean difference).

Mean Difference

Group by Outcome	Study name	Difference in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
CoP area	Lopes, et al. 2017	2,000	0,922	0,850	0,193	3,807	2,170	0,030
CoP area	Gabizon, et al. 2016	0,379	0,417	0,174	-0,437	1,195	0,910	0,363
CoP area	Mesquita, et al. 2015	5,850	2,370	5,619	1,204	10,496	2,468	0,014
CoP area		0,784	0,375	0,140	0,049	1,519	2,091	0,037
CoP velocity	Hyun, et al. 2014	0,050	0,013	0,000	0,025	0,075	3,953	0,000
CoP velocity		0,050	0,013	0,000	0,025	0,075	3,953	0,000
CoPx	Bird, et al. 2012	2,000	0,270	0,073	1,472	2,528	7,420	0,000
CoPx		2,000	0,270	0,073	1,472	2,528	7,420	0,000
CoPy	Donath, et al. 2015	0,600	0,638	0,407	-0,650	1,850	0,941	0,347
CoPy		0,600	0,638	0,407	-0,650	1,850	0,941	0,347

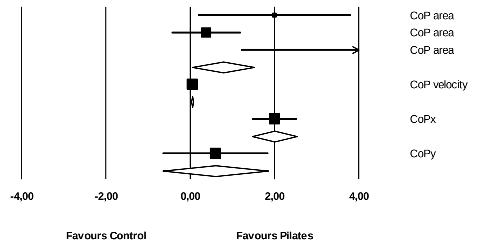

Figure 5. Effects of Pilates on postural balance (Mean difference).