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REVIEW

Effects of Pilates exercises on health-related quality of life in postmenopausal women: a systematic review and meta-analysis

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Abstract

Objective To verify the effects of Pilates exercises on health-related quality of life (HRQoL) in postmenopausal women.

Methods A systematic search was conducted in the following databases: PubMed, Embase, CENTRAL, CINAHL, Web of Science, LILACS, SportDiscus, Scielo, and PEDro. Randomized clinical trials (RCTs) that intervened with Pilates and had HRQoL as an outcome were eligible. The methodological quality of each RCT was assessed using the PEDro scale and the certainty of the evidence using the GRADE system. Meta-analyses were conducted by standardized mean difference (SMD).

Results Initially, 760 records were located. After screening, 11 RCTs were included in the systematic review. Five studies presented low risk of bias (PEDro score ≥ 6). Evidence of very low to moderate certainty demonstrated significant effects in favor of Pilates exercises vs control groups for five of the nine HRQoL domains analyzed: bodily pain (SMD = 0.96), physical functioning (SMD = 0.85), social functioning (SMD = 0.45), role physical (SMD = 0.79), and role emotional (SMD = 0.61). Subgroup analyzes demonstrated that Pilates had a positive impact on more domains whens administered for ≥ 48 sessions (eight domains) vs < 48 sessions (three domains); and when administered on equipment (seven domains) vs mat (three domains).

Conclusion Pilates exercises, in general, allowed significant effects to improve HRQoL in postmenopausal women, especially when performed on equipment and when administered for at least 48 sessions. However, no analysis showed high certainty of evidence, and more RCTs of high methodological quality are needed to confirm these findings.

Keywords Menopause · Postmenopause · Aging · Exercise · Exercise Movement Techniques · Quality of Life · Psychological Well-Being

Plain English summary

This study was important in demonstrating the potential of Pilates exercises to improve the quality of life in postmenopausal women, bringing together the results of several studies already carried out on the subject. Due to hormonal changes that occur after menopause, this population suffers from a series of negative health symptoms, which compromise their quality of life. Physical exercise can be a great option for improving different aspects related to the health of this population, positively reflecting on quality of life, with Pilates exercises being one of the most requested exercises currently. Pilates is characterized as a holistic exercise technique, which works localized muscular resistance, in exercises that can be performed on equipment or using only body weight and accessories. This study indicated that Pilates exercises have the potential to improve several physical and mental components related to quality of life in postmenopausal women. This occurs mainly when Pilates is applied using equipment, requiring at least 48 sessions of intervention for more effective results. The results of this study inspire more quality research to verify the effects of Pilates exercises on the quality of life in postmenopausal women.

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Introduction

Natural menopause occurs due to the permanent cessation of menstruation, resulting from the loss of ovarian follicular activity, and is characterized by 12 consecutive months of amenorrhea, where no other pathological or physiological cause can be clinically determined or identified [1]. Typically occurring between the ages of 46 and 52, the onset of menopause can be influenced by various factors such as socioeconomic conditions, cultural influences, ethnicity, parity, smoking habits, and nutritional factors [2]. In general, women spend at least a third of their lives in the post-menopause period, and due to the phenomenon of population aging, this phase is expected to be even longer in the coming years [3]. During menopause, hormonal concentrations decrease significantly, causing negative symptoms to occur in various body systems, which can compromise health-related quality of life (HRQoL) [4].

A effective approach to counteracting or reversing these factors is to stay physically active during this period. Regular exercise stimulates the development of physical fitness, contributing to the improvement of different physiological and psychological health parameters, which tends to reflect positively on HRQoL [5]. Pilates, a form of physical exercise, has been gaining increasing popularity and attracting more practitioners [6, 7]. The technique is characterized as a form of muscular resistance exercise, which can be performed in two ways: mat or equipment. In mat Pilates, postural adjustments are made so that the practitioner's body weight serves as overload, requiring only a gym mat and optionally accessories, such as a Swiss ball and elastic bands. On the other hand, Pilates equipment involves not only postural adjustments but also relies on springs with varying intensities, providing elastic resistance and serving as the primary method to adjust overload [8].

The technique has been shown to be effective in improving different components of physical fitness, positively reflecting on the performance of activities of daily living in different populations. Consequently, this contributes to both physical and mental health [9]. For example, it has been shown that experienced Pilates practitioners (more than a year of practice) had significantly better general health and mental health when compared to former practitioners. Furthermore, experienced Pilates practitioners demonstrated significantly better physical functioning when compared to novice practitioners (up to three months of practice) [10].

Three systematic reviews recommended Pilates exercises to improve HRQoL; however, the results were not supported by meta-analysis calculations [11–13]. A meta-analysis study observed the effects of Pilates in improving psychological health in older adults; however, several outcomes were analyzed alongside HRQoL, such as fear of falls [14]. Other meta-analyzes considered the effectiveness of traditional resistance exercises for improving HRQoL in older adults, but did not include Pilates exercises [15, 16]. Given the unique characteristics of postmenopausal women and the growing popularity of Pilates exercises, the objective of the present study was to verify the effects of Pilates on HRQoL in postmenopausal women.

Methods

The present study was prospectively registered in PROSPERO (CRD42022339538). The recommendations of the PRISMA protocol [17] were followed. Regarding methodological procedures, the recommendations of the Cochrane collaboration for preparing systematic reviews of intervention studies were followed [18].

Inclusion/exclusion criteria

Only studies that presented the following characteristics were included: (a) Randomized Clinical Trials (RCTs). (b) intervention with Pilates exercises; (c) assessment of HRQoL using a valid instrument; d) postmenopausal women participants. Exclusion criteria: (a) duplicate reports (i.e., identical study published twice); (b) studies that used a co-intervention along with Pilates exercises; (c) studies that included participants with neuromusculoskeletal or cognitive disorders.

Databases and search strategies

The databases used were: PubMed, Embase, CENTRAL, CINAHL, Web of Science, LILACS, SportDiscus, Scielo, and PEDro. No filter was used to limit the date of publications or language. Searches in two clinical trial registration databases (clinicaltrials.gov and apps.who.int/trialsearch) were also carried out in order to find any unpublished studies. In addition, the list of bibliographic references of the included studies was also checked as an attempt to locate works that might not have been captured in the databases. The last search took place on March 9, 2023.

The search strategy was composed of the following keywords, adjusted for each database: ("women" OR "postmenopausal" OR "menopause" OR "perimenopause" OR "climacteric" OR "older adults" OR "aged" OR "elderly" OR "elderly women" OR "older women") AND ("Pilates" OR "Pilates method" OR "Pilates-based exercises" OR "Pilates exercise" OR "clinical Pilates" OR "clinic Pilates" OR "Pilates training" OR "mat Pilates" OR "mat-based

Pilates" OR "equipment-based Pilates") AND ("quality of life" OR "life quality" OR "health-related quality of life" OR "HRQOL").

Study selection

A reviewer carried out the initial search strategy in the databases, extracting titles and abstracts (LCO). Subsequently, this same reviewer performed the extraction of duplicates. Next, two reviewers (PPA and LIMA) blindly read titles and abstracts, excluding works that did not meet the inclusion criteria. The studies that passed this phase were read in full by the same two reviewers, blindly. Any disagreements that were not resolved between the two researchers (PPA and LIMA) were transmitted to a third party (LCO).

Data extraction

The data extracted from each eligible study were (a) name of the authors, year of publication and country of the study; (b) number of participants in each group; (c) mean and standard deviation of age in each group; (d) total duration of the study, weekly frequency of interventions and time of each session; (e) type of Pilates used (mat or equipment); (f) exercises, number of sets and repetitions; (g) activities carried out by other intervention groups; (h) control group activities; (i) instrument used to assess HRQoL; (j) results reported in the original publication; (k) possible adverse events. The same form for data extraction was used by two reviewers (PPA and LIMA) in a blind manner, with disagreements being resolved later by consensus.

Assessment of the methodological quality of studies

The methodological quality of each RCT was assessed using the PEDro scale (Physiotherapy Evidence Database) [19], using the score available in the database itself (www.pedro.org.au/search). When the study was not classified in the PEDro database, two independent reviewers (PPA and LIMA) performed the classification blindly. A third reviewer (LCO) was requested in case of discrepancy. The PEDro scale has 11 items, and the score for the first item is not computed for the purposes of the final score. Therefore, each study receives a final score that can vary from 0 to 10 points. Studies with a final score < 6 are considered to be of low methodological quality (high risk of bias).

Statistical analysis

For meta-analysis, the effect measure was the standardized mean difference (SMD) at the post-intervention moment. The Cochrane Q test for heterogeneity was performed and considered statistically significant if $p \leq 0.10$. Heterogeneity was also quantified with the I^2 statistic, where 0–40% may not be important, 30–60% may represent moderate heterogeneity, 50–90% may represent large heterogeneity, and 75–100% is defined as considerable heterogeneity [18]. Fixed effects models were used when there was no statistically significant heterogeneity; otherwise, random effects models were used. The values referring to the effects of Pilates were considered statistically significant when $p < 0.05$. The effect size of interventions was defined as small (< 0.50), moderate (0.50–0.79), or large (> 0.80) [20]. All analyzes were processed with the RevMan 5.4.

Assessing the certainty of evidence

The certainty of the evidence was blindly classified for each HRQoL domain according to the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) [21], by two independent reviewers (PPA and LIMA), with disagreements being resolved by consensus. GRADE has domains that must be analyzed for each outcome of the meta-analysis: risk of bias; inconsistency; indirectness; imprecision; and publication bias. The GRADE approach contemplates reasons to reduce the certainty of the evidence of the observed effects. Therefore, the final classification of the certainty of the evidence for each outcome can be (a) high (it is unlikely that new researches will change the effect estimate); (b) moderate (it is likely that future researches will have an impact on the effect estimate, and may even modify the estimate); (c) low (future researches will likely have a significant impact on the effect estimate and change the estimate); and (d) very low (results are highly uncertain).

Sensitivity and subgroup analyzes

Sensitivity analysis was performed to verify whether studies with a high risk of bias would be influencing the effect measures of the primary analysis. Therefore, in the sensitivity analysis, studies with low methodological quality (PEDro < 6 points) were eliminated. Regarding subgroup analyzes, two possibilities were viable based on the characteristics and availability of information from the included studies: (a) Pilates intervention time (< 48 sessions vs ≥ 48 sessions) and (b) way of applying Pilates exercises (mat vs equipment). It is noteworthy that the cut-off point for intervention time (48 sessions) was defined post-hoc [18]. This is justified by the fact that it is not possible to establish the cut-off point without knowing the eligible studies, in order to verify from how many sessions most RCTs begin to observe the effects of Pilates on HRQoL.

Results

Qualitative synthesis of studies

Initially, 760 reports were extracted from the databases, in addition to eight clinical trial records. After removing 347 duplicates, 421 titles and abstracts were read, of which 205 were excluded for not meeting the inclusion criteria. Of the remaining 216 reports, 10 were not found (all clinical trial records with an incomplete study or no response from the authors regarding a possible conclusion). Therefore, 206 reports were accessed in full, of which 195 did not meet the eligibility criteria (Supplementary Table 1), leaving 11 studies that were included in the systematic review (Fig. 1).

The included RCTs (Table 1) were published between 2010 [22] and 2021 [23] totaling 434 participants. The studies originated in Iran [23, 24], Brazil [22, 25–29], and Turkey [30–32]. Interventions ranged from six [23] to 52 weeks [32]. In four studies the number of sessions was ≥ 48 [27, 28, 31, 32], and in seven studies, it was < 48 [22–26, 29, 30]. Three RCTs used Pilates equipment [22, 26, 28], seven used mat Pilates [23–25, 29–32] and one study used the combination of both [27]. Only two studies used other forms of intervention for comparison with the Pilates group, which were strength training [25] and whole-body vibration [28]. In seven studies, the control groups maintained their usual routine [22–24, 27, 28, 30, 31]; in one study, participants received lectures [29]; in three other studies, the control group performed minimal intervention [25, 26, 32].

Regarding the assessment of HRQoL, there was a variety of instruments used. Of the 11 RCTs included in the systematic review, eight found significant effects in favor of Pilates compared to control groups for different domains of

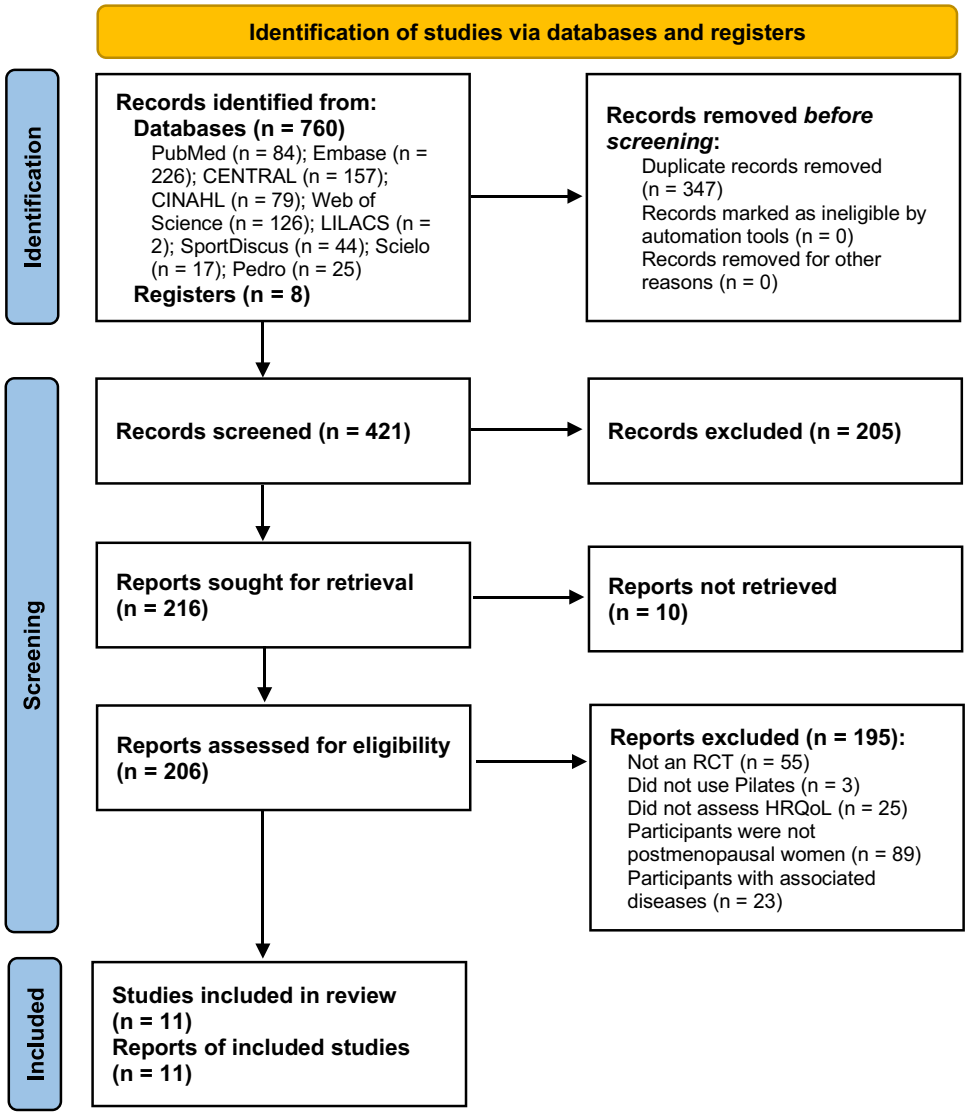

Fig. 1 PRISMA Flow Diagram

Table 1 Summary of studies included in the systematic review

Authors, year and country	Nº participants (mean age and standard deviation)	Study duration, weekly frequency and session duration	Pilates exercise protocol	Other interventions	Control groups	HRQoL assessment	Results reported in the original publication ($p < 0.05$)
Payam and Moghadasi (2021) [23], Iran	30: Pilates = 15 (71.8 ± 6.2) Control = 15 (73.2 ± 5.9)	6 weeks; 6 × week (36 sessions) 45–60 min	Mat Pilates 16 exercises sets × reps: not reported	None	Usual routine	Leipad Questionnaire	Pilates ↑ intragroup (overall score); Pilates ↑ intergroup vs control (overall score)
Pucci et al. (2020) [25], Brazil	41: Pilates = 13 (64.9 ± 3.9) Strength = 14 (67.0 ± 5.8) Control = 14 (69.9 ± 7.2)	12 weeks; 2 × week (24 sessions) 60 min	Mat Pilates 8 exercises sets x reps: 1 × 5–10	Strength training 6 exercises sets x reps: 2–4 × 6–15	Playful and cognitive activities and light walking	WHOQOL-old WHOQOL- bref SF-36	Pilates ↑ intragroup (Whoqol-old: social participation); Strength ↑ intergroup vs Pilates (SF-36: vitality and mental health)
Yildizhan and Aggon (2020) [30], Turkey	36: Pilates = 21 (50.0) Control = 15 (51.9)	8 weeks; 2 × week (16 sessions) 60 min	Mat Pilates 19 exercises sets x reps: 1 × 8	None	Usual routine	Subjective Well-Being Scale	Pilates ↑ intragroup (overall score)
Liposcki et al. (2019) [27], Brazil	20: Pilates = 9 (63.7 ± 3.3) Control = 11 (65.2 ± 3.0)	24 weeks; 2 × week (48 sessions) 30 min	Pilates (mat and equipment) number of exercises: not reported sets x reps: not reported	None	Usual routine	SF-36	Pilates ↑ intragroup (physical functioning, role physical, bodily pain, general health, vitality, social functioning and mental health); Pilates ↑ intergroup vs control (overall score)
Oliveira et al. (2018) [28], Brazil	51: Pilates = 17 (55.5 ± 6.8) Vibration = 17 (56.3 ± 6.4) Control = 17 (54.1 ± 5.2)	24 weeks; 3 × week (72 sessions) 60 min	Pilates equipment 21 exercises sets × reps: 1 × 10	Whole body vibration 20 Hz, 3,2 g (5-min session)	Usual routine	SF-36	Pilates ↑ intergroup vs control (role physical, bodily pain, social functioning and role emotional)
Hassani et al. (2018) [24], Iran	40: Pilates = 20 (65.9 ± 3.0) Control = 20 (64.2 ± 2.6)	8 weeks; 3 × week (24 sessions) 60 min	Mat Pilates 12 exercises sets × reps: 1 × 5–10	None	Usual routine	CASP-19	no difference

Table 1 (continued)

Authors, year and country	Nº participants (mean age and standard deviation)	Study duration, weekly frequency and session duration	Pilates exercise protocol	Other interventions	Control groups	HRQoL assessment	Results reported in the original publication ($p < 0.05$)
Oliveira et al. (2015) [26], Brazil	32: Pilates = 16 (63.6 ± 1.0) Control = 16 (64.2 ± 0.8)	12 weeks; 2 × week (24 sessions) 60 min	Pilates equipment 20 exercises sets × reps: 1 × 10	None	Stretching 20 exercises (3 sets × 30 s)	SF-36	Pilates ↑ intragroup (all domains); Pilates ↑ intergroup vs control (physical functioning, role physical, bodily pain, general health, vitality and mental health)
Angın et al. (2015) [31], Turkey	41: Pilates = 22 (58.2 ± 5.4) Control = 19 (55.9 ± 9.2)	24 weeks; 3 × week (72 sessions) 60 min	Mat Pilates 22–27 exercises sets × reps: not reported	None	Usual routine	QUALEFFO-41	Pilates ↑ intragroup (all domains); Pilates ↑ intergroup vs control (all domains)
Tozim et al. (2014) [29], Brazil	31: Pilates = 14 (67.0 ± 2.8) Control = 17 (64.8 ± 4.0)	8 weeks; 2 × week (16 sessions) 60 min	Mat Pilates 24 exercises sets × reps: not reported	None	Speeches	SF-36	Pilates ↑ intergroup vs control (role physical)
Kuçukçakır et al. (2013) [32], Turkey	60: Pilates = 30 (56.6 ± 5.5) CON = 30 (56.3 ± 5.0)	52 weeks; 2 × week (104 sessions) 60 min	Mat Pilates 9 exercises sets × reps: not reported	None	Chest extension exercises at home (3 sets × 20 reps)	SF-36 QUALEFFO-41	Pilates ↑ intragroup (all domains); Pilates ↑ intergroup vs control (all domains)
Siqueira Rodrigues et al. (2010) [22], Brazil	52 (66 ± 4): Pilates = 27 Control = 25	8 weeks; 2 × week (16 sessions) 60 min	Pilates equipment 10 exercises sets × reps: not reported	None	Usual routine	WHOQOL-old	Pilates ↑ intragroup (sensorial abilities, past, present and future activities, social participation and quality of life index) Pilates ↑ intergroup vs control (quality of life index)

HRQoL health-related quality of life; ↑: significant improvement

HRQoL [22, 23, 26–29, 31, 32]. When Pilates was compared to other forms of physical exercise, one study found no significant differences [28] and another found the superiority of strength training in improving two vitality and mental health domains [25].

Finally, only two RCTs reported adverse events [28, 32]. In the first study, participants in the three groups (Pilates = 11.8%, whole-body vibration = 11.8% and control = 5.8%) suffered falls, with one participant in the control group suffering a fracture. However, all adverse events occurred outside the exercise sessions [28]. In the second study, falls were also reported in both the Pilates group (two falls) and the control group (five falls) [32].

Methodological quality of studies

Assessment of methodological quality, presented in Table 2, demonstrated that of the 11 studies included in the systematic review, six [22, 26, 27, 29–31] presented a high risk of bias (PEDro score < 6 points), with an average score of 5.2 ± 1.4 points.

Quantitative synthesis of studies (meta-analysis)

For each meta-analysis, we analyzed the certainty of the evidence using the GRADE system. For the different analyzes, the certainty of the evidence ranged from very low to moderate. The main problems were linked to the risk of bias, inconsistency, and imprecision (Supplementary Table 2). Figures 2 and 3 present the primary analyzes comparing Pilates vs control groups for different domains of HRQoL.

Regarding the overall HRQoL score, the available evidence showed very low certainty (downgraded due to the risk of bias, inconsistency, and imprecision), indicating that there are no significant differences between the groups (Fig. 2a). In the bodily pain domain, there was moderate-certainty evidence (downgraded due to imprecision) suggesting that Pilates exercises have a significant and substantial effect compared to control groups (Fig. 2b). In the general health domain, the evidence indicated very low certainty (downgraded due to risk of bias, inconsistency, and imprecision) with no significant differences between Pilates and control groups (Fig. 2c).

When observing the physical functioning (Fig. 2d) and social functioning domains (Fig. 3a), moderate-certainty evidence (downgraded by imprecision) suggests that Pilates enables a significant effect of large and small magnitudes, respectively, when compared to the control groups. For the mental health domain, there was very low certainty evidence (downgraded by risk of bias, inconsistency, and imprecision) that there are no significant differences between Pilates and control groups (Fig. 3b).

For the role-physical domain, there was evidence of low certainty (downgraded by inconsistency and imprecision) that Pilates exercises yield a significant effect of moderate magnitude compared to control groups (Fig. 3c). In the vitality domain, very low certainty evidence (downgraded by risk of bias, inconsistency, and imprecision) suggests that there are no significant differences between the Pilates and control groups (Fig. 3d). For the role-emotional domain, there was evidence of moderate certainty (downgraded by imprecision) indicating that Pilates exercises enable a significant effect of moderate magnitude when compared to control groups (Fig. 3e).

Sensitivity analysis

To check whether studies of low methodological quality were influencing the results of the primary analysis, we performed a sensitivity analysis, in which only studies with

Table 2 Methodological quality of the studies included in the systematic review

Study	1†	2	3	4	5	6	7	8	9	10	11	Score‡
Payam and Moghadasi (2021) [23]	+	+	–	+	–	–	–	+	+	+	+	6
Pucci et al. (2020) [25]	+	+	–	+	–	–	–	+	+	+	+	6
Yildizhan and Aggon (2020) [30]	–	+	–	–	–	–	–	+	+	–	+	4
Liposcki et al. (2019) [27]	–	+	–	+	–	–	–	–	–	+	+	4
Oliveira et al. (2018) [28]	+	+	+	+	–	–	+	+	+	+	+	8
Hassani et al. (2018) [24]	+	+	–	+	–	–	–	+	+	+	+	6
Oliveira et al. (2015) [26]	+	+	–	+	–	–	–	+	–	+	+	5
Angın et al. (2015) [31]	+	+	–	+	–	–	–	+	–	+	+	5
Tozim et al. (2014) [29]	+	+	–	–	–	–	–	–	–	+	+	3
Kuçukçakır et al. (2013) [32]	–	+	–	+	–	–	+	+	–	+	+	6
Siqueira Rodrigues et al. (2010) [22]	–	+	–	+	–	–	–	–	–	+	+	4

C1: eligibility criteria; C2: random allocation; C3: concealed allocation; C4: baseline comparability; C5: blind participants; C6: blind therapists; C7: blind assessors; C8: follow-up > 85%; C9: intention-to-treat analysis; C10: between-group comparisons; C11: point estimates and variability. † item not scored. ‡ overall average: 5.2 ± 1.4; +: criterion met; –: criterion not met

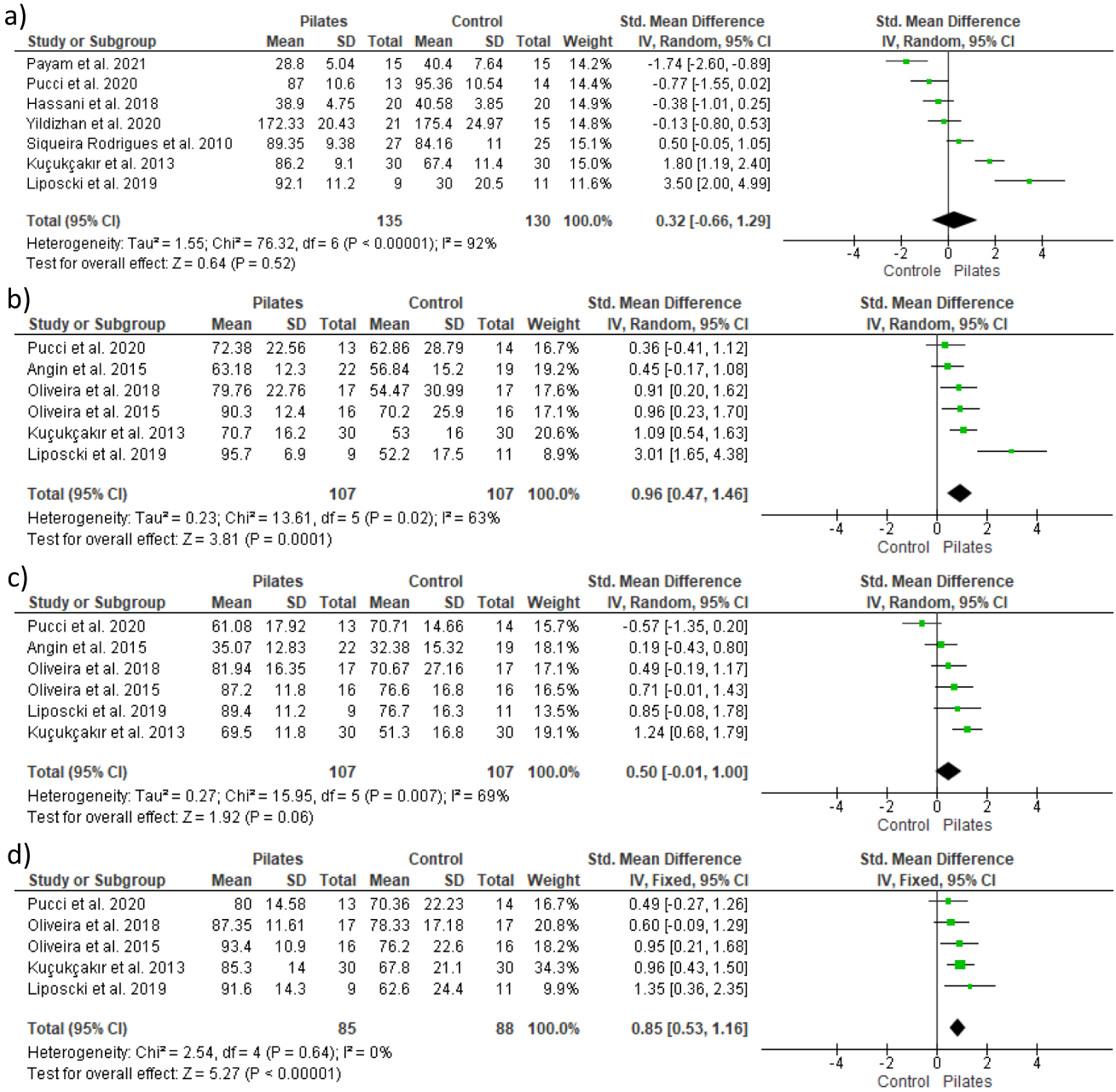

Fig. 2 Primary analysis comparing Pilates exercises vs control groups for HRQoL domains: **a** overall score; **b** bodily pain; **c** general health; **d** physical functioning

a low risk of bias (PEDro score ≥ 6) were maintained. In this case, no results from the primary analyzes comparing Pilates exercises vs. control groups changed (Supplementary Fig. 1).

Intervention time ≥ 48 vs < 48 sessions

When grouping only studies whose intervention time was ≥ 48 sessions, significant effects ranging from moderate (general health, social functioning, vitality, and role emotional) to great magnitude (overall HRQoL score, bodily pain, physical functioning, and role physical) were observed in favor of Pilates exercises vs control groups for different domains of HRQoL, with the exception of the mental health domain (Supplementary Fig. 2). On the other hand, when only studies with intervention time < 48 sessions were grouped, significant effects of moderate magnitude were observed for the domains bodily pain, physical functioning, and role physical, without significant differences for overall HRQoL score, general health,

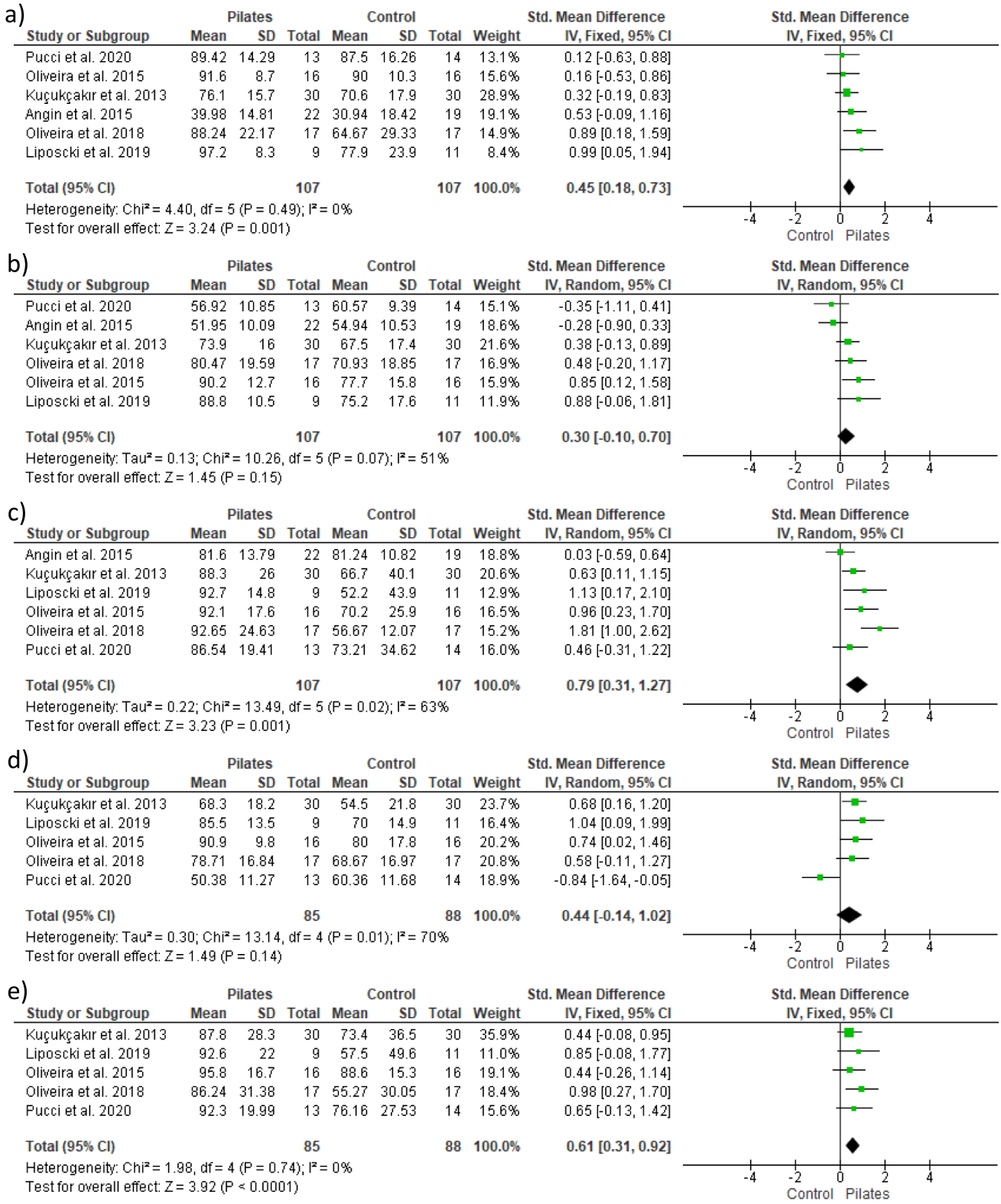

Fig. 3 Primary analysis comparing Pilates exercises vs control groups for HRQoL domains: **a** social functioning; **b** mental health; **c** role physical; **d** vitality; **e** role emotional

social functioning, mental health, vitality, and role emotional (Supplementary Fig. 3).

Pilates on equipment vs mat Pilates

When only studies that used Pilates on equipment were grouped, significant effects ranging from moderate (general health, physical functioning, mental health, vitality, and role emotional) to great magnitude (bodily pain and role physical) were observed in favor of Pilates exercises vs control groups for different domains of HRQoL, except for the overall HRQoL score and social functioning (Supplementary Fig. 4). When only studies that used mat Pilates were grouped, significant effects of small (role physical), moderate (role emotional), and large magnitude (physical functioning) were observed for three domains of HRQoL, without significant differences for overall HRQoL score, bodily pain, general health, social functioning, mental health, and vitality (Supplementary Fig. 5).

Discussion

The present systematic review with meta-analysis aimed to verify the effects of Pilates exercises on improving HRQoL in postmenopausal women. In summary, our findings indicated that the technique improves different domains of HRQoL. It must be considered that, in general, the results were dependent on two moderators: intervention time and form of Pilates application. Our analysis revealed that for Pilates exercises to positively affect HRQoL, a minimun o 48 sessions is necessary, and the application should be on specialized equipment. However, the certainty of the evidence around each outcome ranged from very low to moderate. In other words, there was no high certainty of evidence for any analysis performed. Furthermore, more than half of the RCTs included in the systematic review exhibited a high risk of bias. This implies that the effects observed could be subject to modification with the emergence of new RCTs, underscoring the importance of considering this factor when interpreting the results.

Even so, the current study highlights the potential of Pilates exercises to enhance physical and mental components related to HRQoL in postmenopausal women. The improvement in physical aspects can be directly attributed to the benefits of Pilates exercises. Several studies have demonstrated the positive effects of Pilates on different facets of physical fitness [33, 34], reduced body pain [35, 36], and increased functionality [37]. Consequently, the improvement in physical condition reflects on components related to mental health. In essence, proficiently executing everyday tasks leads to a favorable impact on psychological well-being [38, 39]. Furthermore, as evidenced by different studies, participating in group-based physical exercises, such as Pilates, can yield positive effects on social functioning, mental health and emotional aspects, taking into account the social interaction facilitated by the group activity [40, 41].

The improvement of these components holds particular significance for postmenopausal women, given the different factors that affect physical and mental aspects at this stage of life. Among all the symptoms presented by postmenopausal women, vasomotor symptoms stand out as the most prevalent and exert a substantial impact on HRQoL [42]. Physical exercise emerges as an effective strategy to alleviate these symptoms, and Pilates exercises have already been shown to have a significant impact on reducing climacteric symptoms in postmenopausal women [43]. This is corroborated by the current study's examination of the 11 RCT's included in the systematic review. Notably, only one study [24] failed to observe post-intervention improvements in HRQoL domains. The vast majority reported significant differences in favor of Pilates compared to control groups, encompassing domains related to both physical and mental aspects [22, 23, 25–28, 31, 32].

Although there is no meta-analyzes focused on Pilates exercises to make a direct comparison with the current finding, two previous meta-analyses demonstrated that conventional resistance training allows a significant improvement in different domains of HRQoL in older adults [15, 16]. In the study by Kashi, Mirzazadeh, and Saatchian [15], the authors observed that, out of the nine domains considered in the meta-analysis, conventional resistance training enabled effects of small to moderate magnitude in six domains (physical functioning, mental health, bodily pain, general health, social functioning, and mental component). Likewise, in the research conducted by Hart and Buck [16], conventional resistance training exhibited significant effects ranging from small to large magnitude in seven out of the 10 domains considered (mental component, mental health, vitality, physical component, bodily pain, general health, physical functioning).

In the current study, when considering the nine HRQoL domains, significant positive effects favoring Pilates were observed in five domains (bodily pain, physical functioning, social functioning, role physical, and role emotional), with effects ranging from small to large magnitude. The following domains did not show significant differences: general health, mental health, vitality and overall HRQoL score. It must be considered that, when grouping only studies with intervention time $\geq$ 48 sessions, Pilates exercises were effective in improving all domains, with effects of moderate to large magnitude, with the exception of only one domain (mental health). Nevertheless, the mental health domain showed a significant effect of moderate magnitude in favor of Pilates exercises when the technique was administered using equipment. In this sense, the results of the present study showed

that Pilates exercises performed with equipment, administered for at least 48 sessions, represent the most effective combination for improving HRQoL in postmenopausal women.

Intervention time also proved to be an important moderator in the meta-analysis by Hart and Buck [16], revealing a notable correlation between extended intervention time with resistance training and enhanced HRQoL in older adults. In the current review, several studies had intervention times of between 6 and 12 weeks [22–26, 29, 30]. When these studies were grouped in the subgroup analysis considering intervention time of fewer than 48 sessions, they exhibited significant effects of moderate magnitude in only three HRQoL domains (bodily pain, physical functioning, and role physical) out of the nine considered. Regarding the application of exercieses, the meta-analysis by Kashi, Mirzazadeh, and Saatchian [15] highlighted that significant effects for improving HRQoL in older adults occurred when training involved both machines and free weights in the same session. In contrast, no significant effects were observed for isolated forms of application, such as the use of elastic bands. This discrepancy is likely because the equipment allows better control of the workload during resistance exercises.

Considering this information, Pilates professionals should prioritize the use of equipment for exercise practice. In addition, they should consider an intervention period of at least 48 sessions to improve HRQoL in postmenopausal women. It is recommended to adhere to these parameters until more RCTs are carried out and a high certainty of evidence can be observed. For upcoming RCTs on the topic, we recommend the inclusion of participants in the perimenopausal period. This approach will enable a better understanding of how Pilates exercises can serve as an early prevention strategy, aiming to mitigate the negative effects experienced by women during this physiological period.

Quality/certainty of evidence

In the assessment of the certainty of the evidence, there was evidence of very low to moderate certainty. The primary issues were associated with the risk of bias, inconsistency, and imprecision. Regarding the risk of bias, we observed that no study blinded participants and therapists. However, given that Pilates is an exercise intervention with perceptible stimuli, it is practically impossible to meet these two criteria. Moreover, only one study implemented blind allocation [28], only two blinded the evaluators [28, 38], and the minority performed intention-to-treat analysis [23–25, 28, 30]. Future RCTs should be attentive to these criteria.

Concerning inconsistency, it is noteworthy that six out of the nine primary analyzes exhibited high heterogeneity. This implies that the meta-analysis calculations were conducted by random effects in different analyzes, leading to inconsistency in the results due to discrepancies in effect sizes observed across studies. As for imprecision, it is important to highlight that all meta-analysis calculations conducted did not present an optimal information size. This was due to the few RCTs included, each with small samples. Notably, only five out of the 11 RCTs performed a sample size calculation [25–29], and of these, only one [25] considered HRQoL as an outcome. This aspect may have compromised the sample size of individual studies, posing a critical issue that future RCTs should adress. Lastly, due to the small number of studies included in each meta-analysis (< 10 RCTs), it was not feasible to check possible publication bias using the funnel plot.

Potential biases in the review process

The search was not carried out in all available databases, potentially resulting in the omission of some eligible studies. However, the main databases (PubMed, EMBASE, CENTRAL, CINAHL, Web of Science, SPORTDiscus, LILACS, and PEDro) were thoroughly examined. In addition, two clinical trial registration platforms (clinicaltrials.gov and apps.who.int/trialsearch/) were checked in order to locate any unpublished works. To further mitigate the possibility of overlooking eligible studies, an exhaustive search of all bibliographic references from the included studies in the review was conducted. Another possible bias that must be acknowledge refers to the fact that two authors of the present systematic review are authors of two of the RCTs included [26, 28]. This dual role may unintentionally introduce bias in the interpretation of these studies, and this factor should be duly considered.

Conclusion

The available evidence, of very low to moderate quality, indicates that Pilates exercises effectively improve various domains of HRQoL in postmenopausal women, especially when performed on equipment and sustained for at least 48 sessions. However, as none of the analyzes presented high certainty of evidence, the emergence of new RCTs may modify the observed effects, which should be considered by professionals working with Pilates exercises. In this context, it is recommended that more RCTs of high methodological quality be carried out, with the primary objective of observing the effects of Pilates exercises on HRQoL in postmenopausal women. These studies should prioritize confidential allocation of participants, blinding of evaluators and carrying out intention-to-treat analysis, which were critical points presented by the RCTs included in this review.

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