

The impact of Pilates exercise for depression symptoms in female patients

A systematic review and meta-analysis

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Abstract

Background: The Pilates exercise has recently become an increasingly popular way of exercise in female patients since it is an attractive and low-cost physical exercise modality. Pilates may be a beneficial method of exercise for female patients with depression and anxiety symptoms. However, to date, there has been no attempt to collate this literature. This review aims to systematically assess and meta-analyze the efficacy of Pilates exercise for female patients with depression and anxiety symptoms and inform evidence-based guidelines for exercise prescription.

Methods: Five electronic databases (Scopus, MEDLINE/PubMed, Embase, Web of Science, and the Cochrane Library) were systematically searched up to January 2023 to examine randomized controlled trials (RCTs) focused on the effects of Pilates exercise for female patients with depressive disorders and individuals with elevated levels of depression were included. The primary outcomes were the severity of depression, and the secondary outcomes were anxiety. Statistical analyses were performed using Stata version 15.1 software with a 95% confidence interval (Registration number: CRD42023426522), and the PEDRO Scale was used to evaluate the risk of bias for RCT.

Results: 18 RCTs with 827 female patients were included. The methodological quality of the RCTs was considered an A level in 4 studies, B level in 13, studies, and C level in 1 study investigation. The meta-analysis showed that there was moderate evidence for the Pilates exercise significantly improved the severity of depression symptoms (SMD = -0.73; 95% CI -0.86 to -0.59; $P < .01$) and anxiety symptoms (SMD = -0.62; 95% CI -0.79 to -0.46; $P < .01$).

Conclusions: Pilates exercise could reduce levels of depression and anxiety in female patients with depression and anxiety symptoms. Pilates exercise can be used as a potential ancillary program to improve depression and anxiety symptoms for female patients.

Abbreviations: CBT = cognitive behavioral therapy, CI = confidence interval, ES = effect size, PE/PEG = Pilates exercise, RCT = randomized controlled trials, SMD = standardized mean differences.

Keywords: anxiety, depression symptoms, female patients, meta-analysis, Pilates, review

1. Introduction

Depressive symptoms and depressive disorders are common mental health problems in adult populations.^[1] Most studies showed that depression is more common among females than males, and with a worldwide incidence of an increasing trend of annual growth.^[2-4] Indeed, the adverse effects of female depression can decrease immune function and increase symptoms of illness or inflammation,^[5] increase the load of disease among females in the elderly,^[6] and even negatively

affect maternal physical health and increase the risk of suicide.^[7] Depression in female carries a heavy burden on society, families, and individual patients.^[8,9] For this reason, this study will focus on alleviating and preventing depression and depressive symptoms in female patients. Currently, there are established some effective interventions available for the treatment of depression in adults that include pharmacotherapy and psychotherapy (such as cognitive behavioral therapy [CBT]) and exercise^[10-12] In drug therapy, there is evidence that alterations in monoamine (e.g., noradrenaline, selective

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Informed consent was obtained from all subjects involved in the study.

The authors have no conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Table 1
Search strategy.

Databases	Search strategy	Result (approximately)
Scopus	#1: TI-AB-KW ("Pilates" OR "Pilates training" OR "Pilates based exercises") #2: TI-AB-KW ("depression*" OR "depressive*" OR "depressive disorder*" OR "depressive symptom*") #3: TI-AB-KW (randomized OR placebo OR RCT) #4: #1 and #2 and #3 PUBLICATION YEARS: LIMIT-TO (PUBYEAR 2023–2000)	1447 921,456 1,553,406 59
PUBMED	#1: [Title/Abstract] ("Pilates" OR "Pilates Training" OR "Pilates Based Exercises") #2: [Title/Abstract] ("Depression*" OR "Depressive*" OR "Depressive Disorder*" OR "Depressive Symptom*") #3: [Title/Abstract] ("randomized" OR "placebo" OR "RCT") #4: #1 and #2 and #3 Filters: Publication date from 2000/01/01 to 2023/07/01	792 486,458 804,741 27
Embase	#1: TI-AB-KW:("Pilates" OR "Pilates training" OR "Pilates based exercises") AND [2000–2023]/PY #2: TI-AB-KW:("depression*" OR "depressive*" OR "depressive disorder*" OR "depressive symptom*") AND [2000–2023]/PY #3: TI-AB-KW:("randomized controlled trial" OR "randomized" OR "placebo" OR "RCT") AND [2000–2023]/PY #4. #1 AND #2 AND #3	1402 886,827 1,672,668 54
Web of Science	#1: TOPIC:("Pilates" OR "Pilates Training" OR "Pilates Based Exercises") #2: TOPIC:("Depression*" OR "Depressive*" OR "Depressive Disorder*" OR "Depressive Symptom*") #3: TOPIC:("randomized" OR "randomized controlled trial" OR "placebo" OR "RCT") #4: #1 and #2 and #3 Refined by: PUBLICATION YEARS: (2023–2000) Indexes = SCI-EXPANDED, SSCI, CCR-EXPANDED, IC Timespan = All years	1241 727,623 1,217,775 48
Cochrane	#1: TI-AB-KW:("Pilates" OR "Pilates Exercise*" OR "Pilates Based Exercises " OR "Pilates Training*") #2: TI-AB-KW:("depression*" OR "depressive*" OR "depressive disorder*" OR "depressive symptom*") #3: TI-AB-KW:("randomized" OR "placebo" OR "RCT") #4: #1 and #2 and #3 Year First Published: Custom Range:2000 to 2023	987 99,803 1,244,613 62

RCT = randomized controlled trials; TI-AB-KW = Title-Abstract-Keywords.

serotonin reuptake inhibitors, dopamine)^[13] or other agents (such as tricyclic antidepressants, fluoxetine, agomelatine)^[14] play a significant role in the pathophysiology of depression. Nonetheless, relevant studies have shown that the drug therapy effect is not ideal.^[15] CBT has been confirmed to significantly improve effect sizes (ESs) in the treatment of female patients with depression.^[16] However, CBT requires a relatively long time,^[17] has high drop-out rates,^[18] and is expensive.^[19] Therefore, we need to explore further the treatment of female's depression with good efficacy, low cost, convenient operation, and minor side effects.

Exercise intervention has been recognized as an alternative or supplementary method for the treatment of female patients with depression,^[20–23] and Pilates exercise (PE/PEG) has been gaining popularity in recent years.^[24–26] PE/PEGs were developed by Joseph Hubertus Pilates in the 1920s and were initially called Contrology.^[27] Pilates is a type of whole-body exercise aiming to develop better body awareness and functional, improved posture and breathing.^[26,28] In addition, the Pilates program become a superior choice for exercise weight loss in the female patient population due to its obvious burning fat effect^[29,30] enhance core strength^[31,32] correcting poor posture^[33,34] relieve joint damage and delay spinal damage.^[35,36]

At present, several meta-analyses and systematic reviews have demonstrated that Pilates can achieve a moderate to large ES (standardized mean differences [SMD]: 0.62; 0.83) in the treatment of depression.^[37] However, Boing L et al and Leite B et al showed no effect of PE/PEG on depressive symptoms of breast cancer female^[38,39] which led to some confusion among researchers and clinicians about the PE/PEG in the treatment of female's depression. Therefore, this review aimed to systematically review and meta-analysis the ES of Pilates and analyze different PE/PEG strategies for female patients with depressive disorders and individuals with elevated levels of depression through a meta-analysis of Randomized Controlled Trials.

2. Materials and methods

2.1. Protocol and registration

This systematic review was planned and conducted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines^[40] and the recommendations of the Cochrane Collaboration.^[41] The selected search strategy and methods of analysis were registered in the PROSPERO protocol (Registration number: CRD42023426522).

2.2. Data sources, search strategy, and study selection procedure

The search strategies were designed to retrieve all studies that assessed the efficacy of the depression and anxiety symptoms of Pilates interventions in female patients. The following electronic databases were searched from their inception through 2023, with the final day of retrieval being July 1, 2023: Scopus, PubMed, Embase, Web of Science, and the Cochrane Library.

The literature search was constructed around the following search terms, Boolean operators, and combinations were used: "Pilates" OR "Pilates Training" OR "Pilates Exercise" OR "Pilates Based Exercises" AND "Depression*" OR "Depressive*" OR "Depressive Disorder*" OR "Depressive Symptom*" OR "Anxiety." The search strategies and results for each electronic database is presented in Table 1.

Two investigators (M. J and W. Y) independently selected studies for inclusion using predetermined criteria for eligibility. Studies were first screened according to the titles and abstracts and obtained the full texts of potentially eligible articles. Second, the reviewers will also retrieve the full paper of each potentially eligible article to determine whether those studies can be finally included. In all cases, any disagreement will be resolved through discussion between 2 reviewers and, if necessary, consultation with the third reviewer (Z.Z) until a consensus was reached.

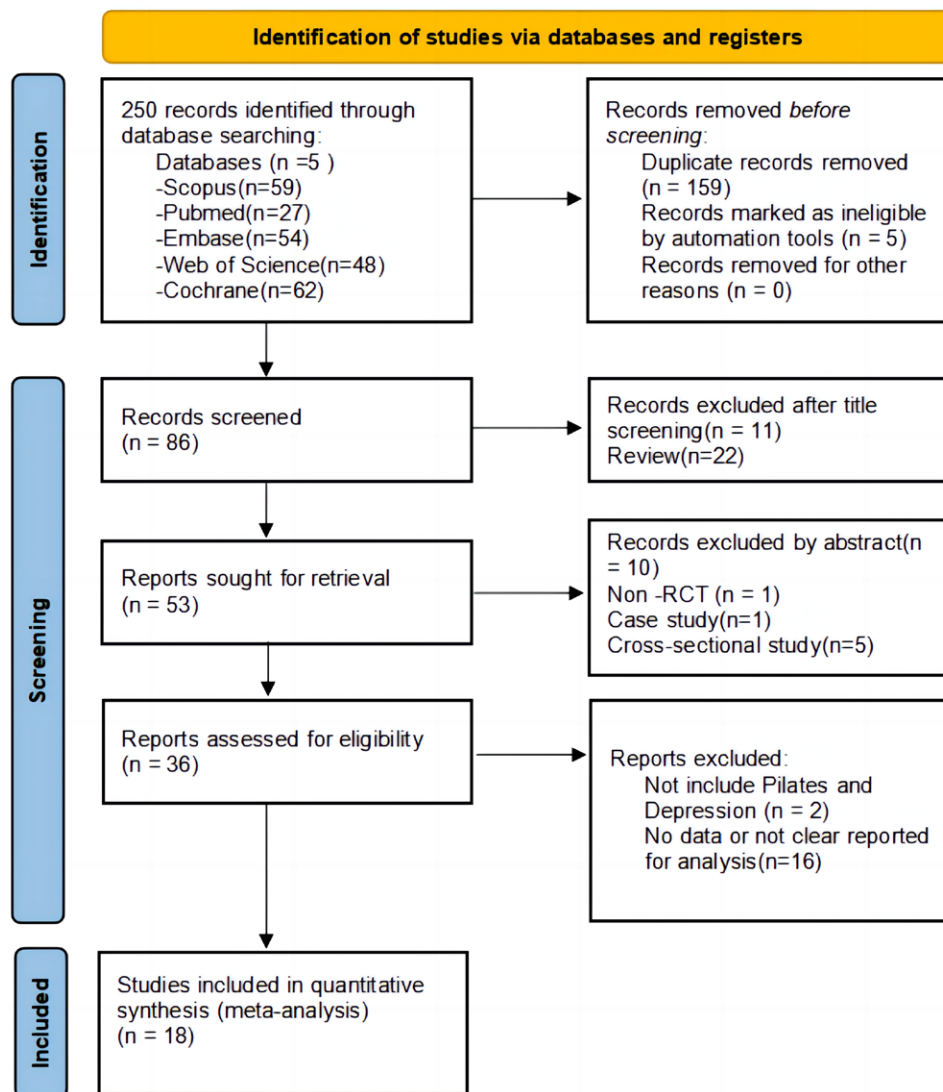


Figure 1. Flowchart of the process of searching and selecting the final studies for the systematic review.

2.3. Eligibility criteria (inclusion and exclusion criteria)

Inclusion criteria: (1) *Study*: Randomized controlled trials (RCT). (2) *Participants*: Female with depressive symptoms or depressive disorders. (3) *Interventions*: PE/PEG. (4) *Outcome measure*: (a) primary outcome: improvement in depressive symptoms was measured as the number of female patients who reach remission as measured by the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-V)^[42] or the International Classification of Disease, Tenth edition (ICD-10)^[43] criteria, the Beck Depression Inventory (BDI),^[44] Edinburgh Postnatal Depression Scale,^[45] Quick Inventory of Depressive Symptomatology,^[46] the General Health Questionnaire,^[47] Calgary Depression Scale for Schizophrenia^[48] or the Hospital Anxiety and Depression Scale^[49] or any other validated depression scale. (b) Secondary outcomes: improvement in anxiety symptoms was measured using clinician-rated scales, such as the Hospital Anxiety and Depression Scale (HADS-A),^[49] the State-Trait Anxiety Inventory,^[50] Brief Psychiatric Rating Scale^[51] or any other validated anxiety scale.

The mean change in depressive and anxiety symptoms was the outcome measure of interest from baseline to post-intervention. SMD (95% confidence interval, CI) was calculated to compare depressive and anxiety scores between intervention and control groups.

Exclusion criteria: (1) reviews, observational studies, abstract-only articles, and non-RCT studies; (2) duplicated studies; (3) no data or not clear reported for analysis. (4) The control group underwent methods other than the usual nursing approaches, such as taking medications for antidepressants or anxiety.

2.4. Data extraction and management

Relevant data were extracted independently from the included articles by our 2 reviewers (M. J and W. Y) using an a priori-developed data extraction form. The extraction information includes the first author, published year, country, the essential characteristics of participants, the study design, interventions, control intervention, outcome measures, and adverse effects of the PE/PEG intervention. Furthermore, any disagreements between the 2 reviewers were discussed with the third reviewer (Z.Z) until a consensus was reached.

2.5. Quality assessment of each eligible studies

The methodological quality of each selected RCT included in the systematic review was assessed by 2 researchers independently by the PEDRO Scale (Physiotherapy Evidence Database Scale).^[52] The PEDRO Scale comprises 11 items, 10 of which

Table 2
Characteristics of the included studies.

Study	Characteristics of patients				Pilates exercise intervention				Depression indicator	Anxiety indicator
	Country	Sample size (PEG/CG)	Gender (M/F)	Age (years) (PEG/CG)	Type	Duration (weeks)	Exercise intervention	HADS-D		
Agustín Albar-Alemazán (2019) ^[61]	Spain	55/55	PEG:0/55 CG:0/55	69.15 ± 8.94	Pilates	12 weeks;3/weeks;60 min	PEG: ① Warm-up (10 min); ② Main Pilates training (35 min); ③ Cool-down (15 min)	CG:NR	HADS-D	HADS-A
Eda Akbaş (2021) ^[62]	Turkey	10/10	NR	PEG:40.40 ± 8.39 CG: 39.12 ± 6.68	Pilates	6 weeks; 2/weeks; 40–50 min	PEG: ① Warm-up (10-min); ② Pilates exercise (20–30 min); ③ Cool-down (10-min).	CG: fitness, social interaction activities	CDSS	BPRS
Sevilay Batbay (2021) ^[63]	Turkey	28/25	PEG:0/28 HEG:0/25	PEG: 49.3 ± 10.4 HEG: 48.4 ± 9.3	Home Pilates	8 weeks;3/weeks; 60min; 10 repetitions	PEG: ① One session on the key aspects of Pilates; ② Basic and intermediate Pilates mats exercises.	HEP: Basic home Pilates exercise program.	BDI	NR
Leoneisa Boing 2022 ^[64]	Brazil	25/24	PEG:0/25 CG:0/24	PEG: 54.3 ± 10.4 CG: 56.8 ± 11.2	Pilates and aerobic	16 weeks; 3/weeks; 60 min	PEG: ① Warm up and stretching; ② Main Pilates; ③ Relaxation.	CG:3 educational discussions and continue routine activities.	BDI	NR
V.S. Curi (2018) ^[64]	Portugal	31/30	PEG:0/31 CG:0/30	PEG: 64.25 ± 0.14 CG: 63.75 ± 0.08	Pilates	16 weeks; 2/weeks; 60 min	PEG: ① The Classical Pilates Method; ② The intermediate level exercises.	CG: ① Not perform any physical activity; ② Attended monthly meetings at a group.	GHQ-12	NR
Tatiana de Bem Fretta (2021) ^[65]	Brazil	18/16	PEG:0/18 CG:0/16	PEG: 53.33 ± 8.58 CG: 57.50 ± 13.02	Pilates	16 weeks;3/weeks; 60 min	PEG: ① Warm-up (20 min); ② Main part (30 min); ③ Cool-down (10 min)	CG: Routine activities plus three meetings.	BDI	NR
S. EYGOR 2010 ^[66]	Turkey	27/15	PEG:0/27 HEG:0/15	PEG: 48.52 ± 7.62 HEG: 49.73 ± 8.71	Pilates	8 weeks;3/weeks; 60min	PEG: ① Warm-up exercises; ② Pilates exercises; ③ Cool-down exercises; ④ Walking exercise of 20–30min a day.	CG: Walking of 20–30 minutes a day.	BDI	NR
Karl M. Fleming 2019a ^[67]	Ireland	11/7	SP:0/5 HBP:0/6 WL:1/6	SP: 53.8 ± 7.95 HBP: 46.0 ± 9.4 WL: 51.3 ± 6.8	Pilates	8 weeks; 2/weeks; 60min	① Warm Up; ② Basic Mat Exercises; ③ Cool down (1 Repetition of Stretch)30–60 seconds.	CG: Maintain pretrial activity levels.	HADS-D	HADS-A
Karl M. Fleming 2021b ^[68]	Ireland	36/33	SP/HBP:0/36 WL:0/33	SP/HBP: 46.6 ± 9.6 WL: 46.5 ± 11.0	Home Pilates	8 weeks; 2/weeks; 60min	PEG: ① Warm Up; ② Basic Mat Exercises; ③ Cool Down (1 Repetition of Stretch)30–60 seconds.	CG: Maintained pre-intervention activity levels	QIDS; HADS-D)	HADS-A; STAI

(Continued)

Table 2
(Continued)

Study	Characteristics of patients				Pilates exercise intervention				Depression indicator	Anxiety indicator
	Country	Sample size (PEG/CG)	Gender (M/F)	Age (years) (PEG/CG)	Type	Duration (weeks)	Exercise intervention	CG: Did not participate in any exercise.		
Hyun-Bin Kim 2022 ^[68]	Korea	8/8	PEG:0/8 CG:0/8	PEG: 39.71 ± 2.01 CG: 38.14 ± 1.39	Home Pilates	8 weeks; 2/weeks; 50 min	PEG: ① Warm-up; ② Main exercise; ③ Cool-down; ④ 50–60% of the max heart rate.	CG: Did not participate in any exercise.	EPDS	NR
Fadime Küçük, PT 2016 ^[70]	Turkey	11/9	PEG:4/7 CG:3/6	PEG: 47.2 ± 9.5 CG: 49.7 ± 8.9	Clinical Pilates	8 weeks; 2/weeks; 45–60 min	PEG: ① Warm-up (10 min); ② Mat exercises (25–45 min); ③ Cool-down (10 min); ④ 50–60% of the max heart rate.	CG: Traditional exercises and coordination exercises.	BDI	NR
Bruna Leite 2021 ^[69]	Brazil	18/16	PEG:0/18 CG:0/16	PEG: 53 ± 8 CG: 58 ± 11	Pilates and aerobic	16 weeks; 3/weeks; 60 min	PEG: ① Initial part (20 min); ② Main part (30 min); ③ Final part (10 min); ④ Pilates exercise principles; ⑤ Mat-work Pilates exercises.	CG: Continue routine activities	BDI	NR
Asuman Saltan 2020 ^[71]	Turkey	29/35	PEG:6/23 CG:4/31	PEG: 18.82 ± 1.07 CG: 19.42 ± 1.38	Pilates	12 weeks; 3/weeks; 150 min	PEG: ① Pilates exercise principles; ② Mat-work Pilates exercises.	CG: Ordinary regular physical activity.	BDI	NR
Yazgi Senturk 2021 ^[72]	Turkey	28/27	OPG:0/28 CG:3/24	OPG: 36.8 ± 9.6 CG: 41.1 ± 9.7	Clinical Pilates	8 weeks; 2/weeks; 45–60 min	CPE: ① Warm-up (5 min); ② Mat Pilates (35–50 min); ③ Cool down (5 min); ④ Pilates exercise principles; ⑤ Mat-work Pilates exercises.	CG: Daily life activities.	BDI	STAI
Rodrigo Luiz Vancini 2017 ^[73]	Brazil	22/20	PEG:1/21 CG:6/12	PEG: 55.9 ± 6.6 CG: 41.7 ± 12.6	Pilates and aerobic	8 weeks; 3/weeks; 60 min	PEG: ① Warm-up (10 min); ② Pilates (45 min); ③ Cool-down (5 min); ④ Synchronized breathing Practice; ⑤ Pilates ball exercise.	CG: Ordinary regular physical activity.	BDI	STAI
Peim Yildirim 2022 ^[74]	Turkey	17/17	PEG:0/17 CG:0/17	PEG: 30.8 ± 7.0 CG: 28.8 ± 5.6	Clinical Pilates	12 weeks; 2/weeks; 60 min	PEG: ① Warm-up stretching; ② Aerobic Pilates; ③ Cool-down.	CG: Not prescribed an exercise regimen.	HADS-D	HADS-A
Hulya Yucel 2018 ^[75]	Turkey	24/21	PEG:0/24 CG:0/21	PEG: 58.50 ± 7.00 CG: 53.50 ± 9.00	Pilates	12 weeks; 3/weeks; 45–70 min	PEG: ① Warm-up stretching; ② Aerobic Pilates; ③ Cool-down.	CG: Routine diet and medical follow-ups.	HADS-D	HADS-A
All avari 2021 ^[76]	Ireland	30/30	PEG:0/30 CG:0/30	PEG: 62.30 ± 3.13 CG: 62.60 ± 3.13	Pilates	8 weeks; 3/weeks; 60 min	PEG: ① Warm up; ② Pilates; ③ Cool-down.	CG: NR	BDI	NR

BDI = Beck depression inventory; BPRS = Brief Psychiatric Rating Scale; CDSS = Calgary Depression Scale for Schizophrenia; CG = Control Group; EPDS = Edinburgh Postnatal Depression Scale; F = female; GHQ-12 = The General Health Questionnaire; HADS-A = The Hospital Anxiety and Depression Scale; HADS-D = The Hospital Anxiety and Depression Scale; HBP = Homebased Pilates; HEG = Home Exercise Group; M = male; NR = Not Reported; PEG = Pilates Exercise Group; QIDS = Quick Inventory of Depressive Symptomatology; RCT = randomized controlled trial; SP = Supervised Pilates; STAI = The State Trait Anxiety Inventory; WL = Waitlist.

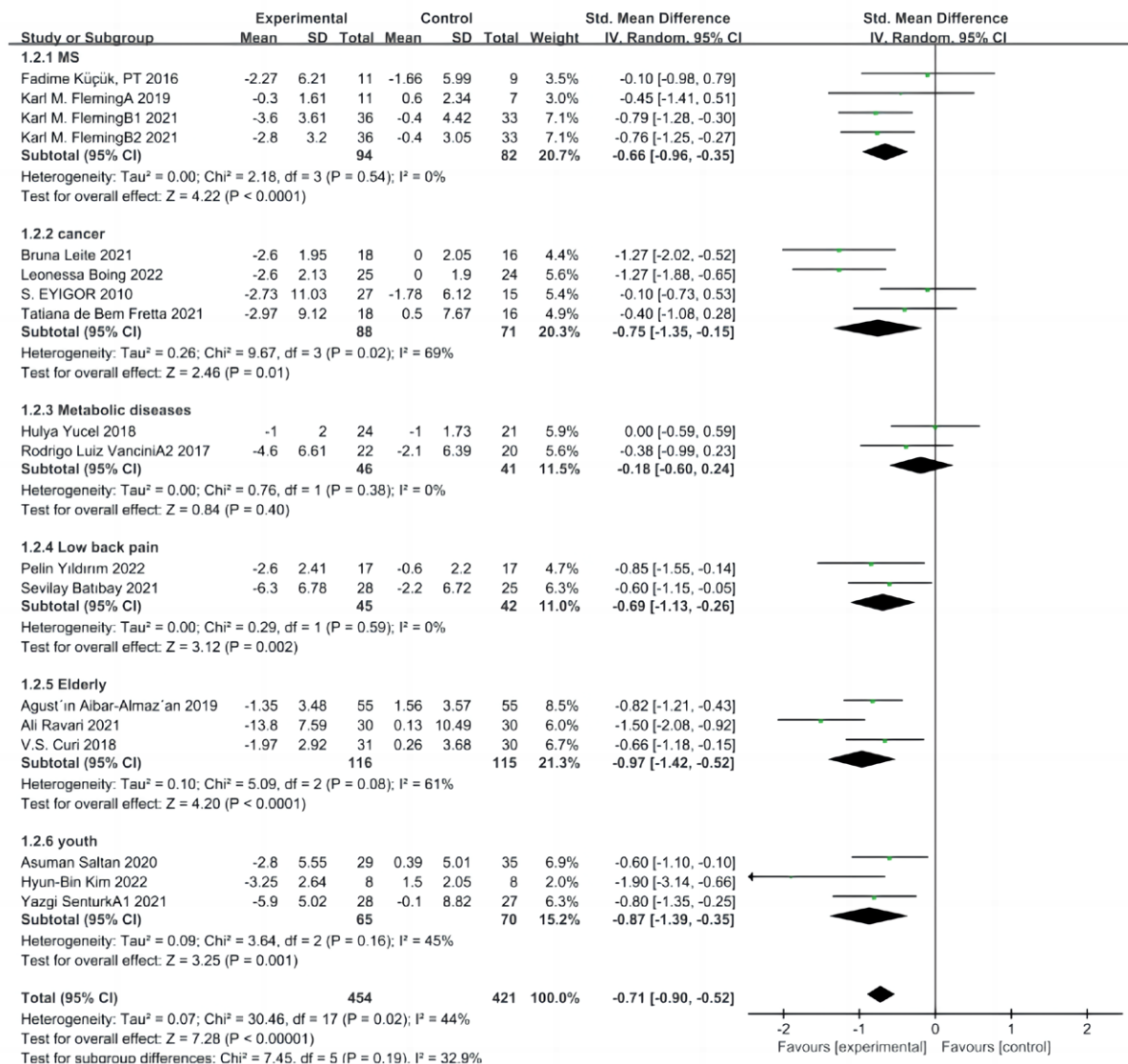


Figure 3. Effect of the Pilates exercise for depression symptoms in female patients.

3. Result

3.1. Eligibility of studies selection

According to the search strategy, a total of 250 articles were found from 6 databases and other resources. After removing the duplicate and not recognized by Endnote Library, studies 86 remained. A total of 33 articles were removed after the title screen for non-relevant articles (n = 11) and review (n = 22). Fifty-three studies remained to read their abstracts. After reading the abstracts, the remaining 36 articles were further screened by reading the full-text article. Eighteen studies were removed owing to not including Pilates and depression (n = 2) and no or unclear outcome measures (n = 16). Thus, 18 studies with 827 female patients met the criteria to be included in our meta-analysis. The search strategy can be found in Figure 1.

3.2. Characteristics of eligible studies

Study characteristics of the sample size, sex, age, country, interventions, outcomes assessment, and results are shown in Table 2. A specific exercise program for PE/PEGs can be found in Table 2.

(1) Setting and participant characteristics. Of the 250 studies initially identified records, only 18 eligible RCT studies met the inclusion criteria and were included in the meta-analysis. Of the included studies, 8 were conducted in Turkey, 4 in Brazil, 3 in Ireland, 1 in Spain, 1 in Portugal, and 1 in Korea. There were 827 participants in total, 417 female and 11 men were in the PE/PEG group, 382 female and 17 men were in the control group, the most significant sample was 110 participants, and the smallest sample was 16 participants. Underrepresented men (3%) were not involved in this study. The age of female participants ranged from 17 to 78 years.

(2) Intervention characteristics. The main characteristics of the PE/PEG interventions for each study are described in Table 2. The interventions used by the studies were Pilates-Based Exercises, Pilates mat exercises, Home-based Pilates, Pilates and aerobic training, Online Pilates, and clinical Pilates. The intervention duration of the studies ranged from 6 to 16 weeks, and included sessions 40 to 70 minutes long, which were performed 2–3 times per week.

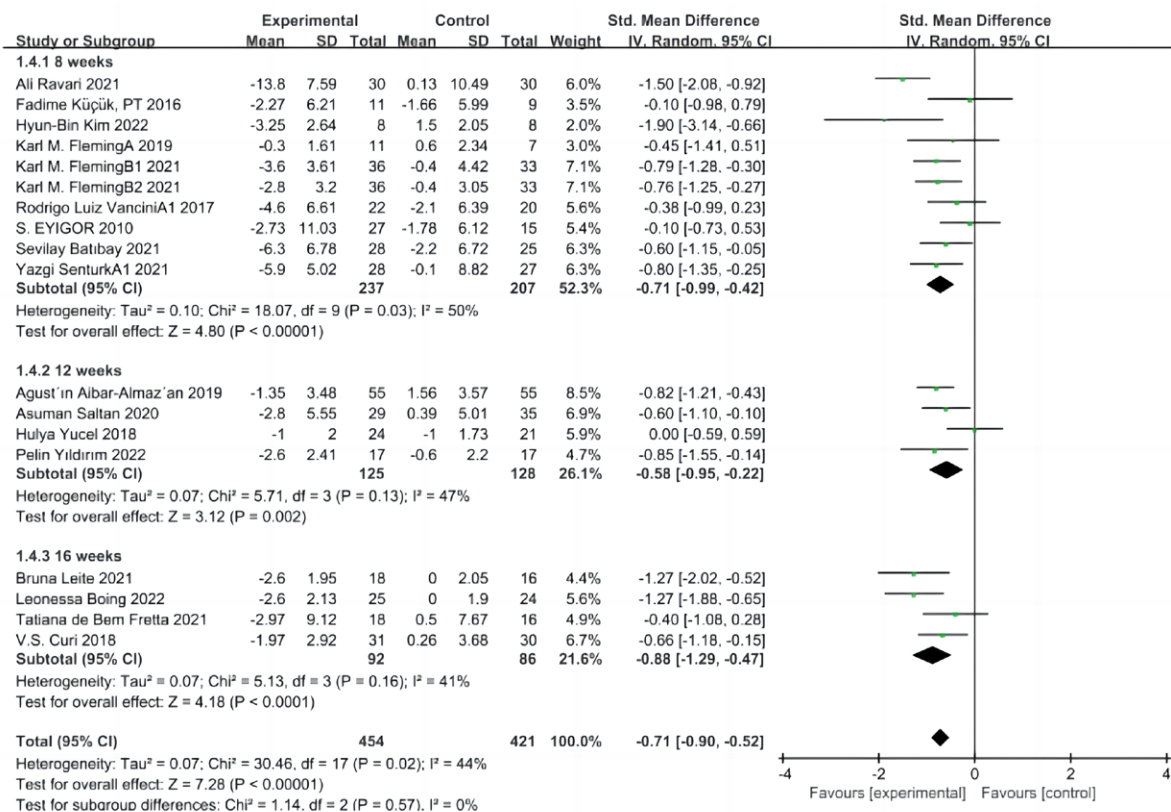


Figure 4. Effect of the Pilates exercise for anxiety symptoms in female patients.

3.3. Methodological quality assessment

Regarding the quality evaluation of the original studies the Cochrane Risk of Bias tool will be used to evaluate the possible potential risk of publication and the corresponding score will be given to each original study, but it is worth noting that out of the RCTs that use exercise as an intervention, the double-blind method is not possible to a certain extent because the participants in the experimental group of this type of studies are required to sign an informed consent form prior to the start of the experiment. Therefore, in the option of the double-blind method, high-risk studies can be considered less intrusive to the experimental results.¹⁵⁸¹ As shown in Figure 2.

3.4. Outcome measures

The instruments used to measure and assess depression symptoms were the Beck Depression Inventory in 10 studies, the Hospital Anxiety and Depression Scale in 5 studies, the Calgary Depression Scale for Schizophrenia in 1 studies, as well as the Quick Inventory of Depressive Symptomatology, the Edinburgh Postnatal Depression Scale and the General Health Questionnaire; moreover, 12 studies in RCT assessed symptoms of anxiety, using the Hospital Anxiety and Depression Scale in 5 studies, the State-Trait Anxiety Inventory in 6 studies, and Brief Psychiatric Rating Scale in 1 study.

3.5. Analyses of overall effect

(1) Depression.

For depression symptom outcome indicators, all 18 studies were included. Figure 3 demonstrates that the meta-analysis of 18 studies showed the PE/PEG to significantly reduce depression symptoms in female patients (SMD = -0.71; 95% CI -0.90 to -0.52; P = .02; heterogeneity: I² = 44%;

P = .022). Based on Cohen categories, these effects were of large ESs.

(2) Anxiety.

For the anxiety symptoms outcome indicator, 8 articles compared the difference in anxiety symptoms between the PE/PEG group and the control group before and after the experiment among the 18 included articles. Figure 4 shows that the meta-analysis of 8 studies demonstrates the PE/PEG to significantly reduce anxiety symptoms in female patients (SMD = -0.58; 95% CI -0.78 to -0.38; P < .01; heterogeneity: I² = 29%; P = .286). And based on Cohen categories, these effects were of medium size.

3.6. Subgroup analysis

Since the study included females with different characteristics, we classified the subgroups according to the characteristics of the experimental participants involved in each of the original studies, and in the same way, we analyzed the duration of the exercise intervention in the corresponding subgroups. (1) Subgroups of young adults, middle-aged and old adults, patients with multiple sclerosis, patients with metabolic diseases, and patients with chronic low back pain were categorized according to the characteristics of the different populations, as shown in Figure 5. (2) Subgroups of 8, 12 and 16 weeks were divided according to the duration of the exercise intervention, as shown in Figure 6.

For symptoms of depression, it is likely that PE/PEG was more helpful for middle-aged and older patients (SMD = -0.97, 95% CI = [-1.42, -0.52]), whereas for duration of exercise, it appears that the longer 16-week Pilates intervention was more effective (SMD = -0.88, 95% CI = [-1.29, -0.47]). For symptoms of anxiety, it is likely that PE/PEG was more helpful for middle-aged and older patients (SMD = -1.08, 95% CI = [-1.49, -0.68]), while the longer 12-week Pilates intervention seemed to be more effective in terms of duration of exercise (SMD = -0.78, 95% CI = [-1.09, -0.47]).

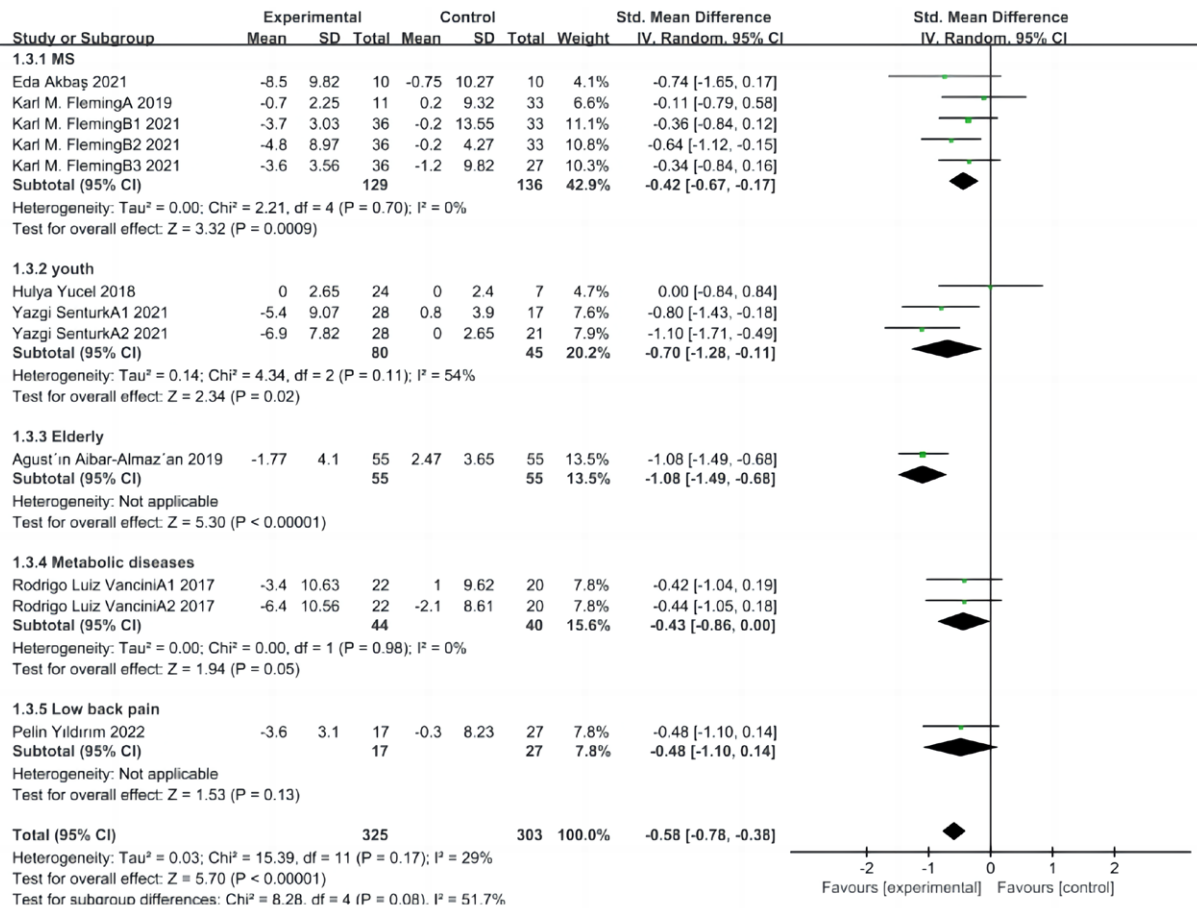


Figure 5. Effect of the Pilates exercise for depression symptoms in female patients with different characteristics.

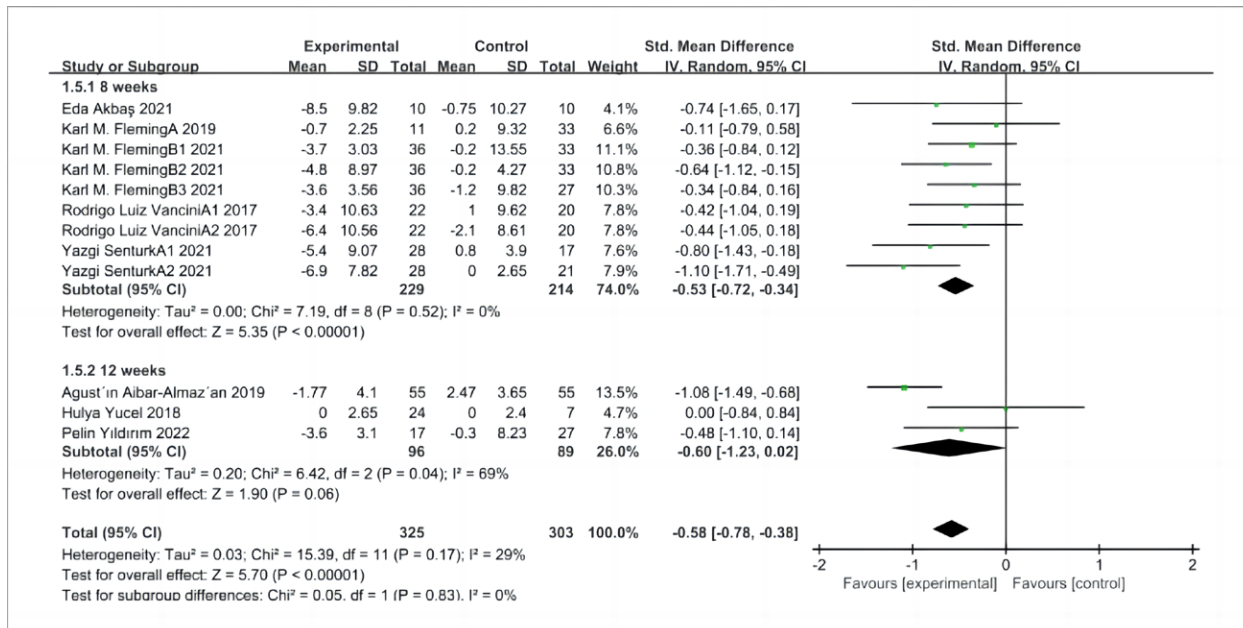


Figure 6. Effect of the Pilates exercise in different cycles for depression symptoms in female patients with different characteristics.

3.7. Sensitivity analysis

In this study, sensitivity analysis was performed by excluding separate articles, alternating the analysis model alteration,

and selecting the ES. Since there was moderate heterogeneity among the 18 studies included ($I^2 = 43.6\%$; $P = .022$) in the Pilates intervention for depression in female patients, Thus,

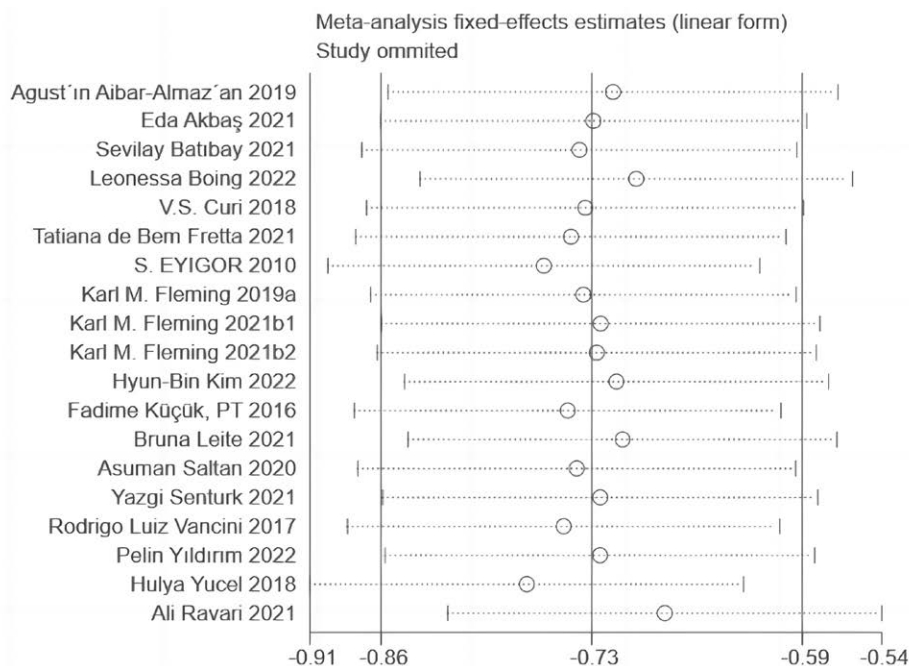


Figure 7. Sensitivity analyses illustrating the effects of the Pilates exercise on depression symptoms in female patients.

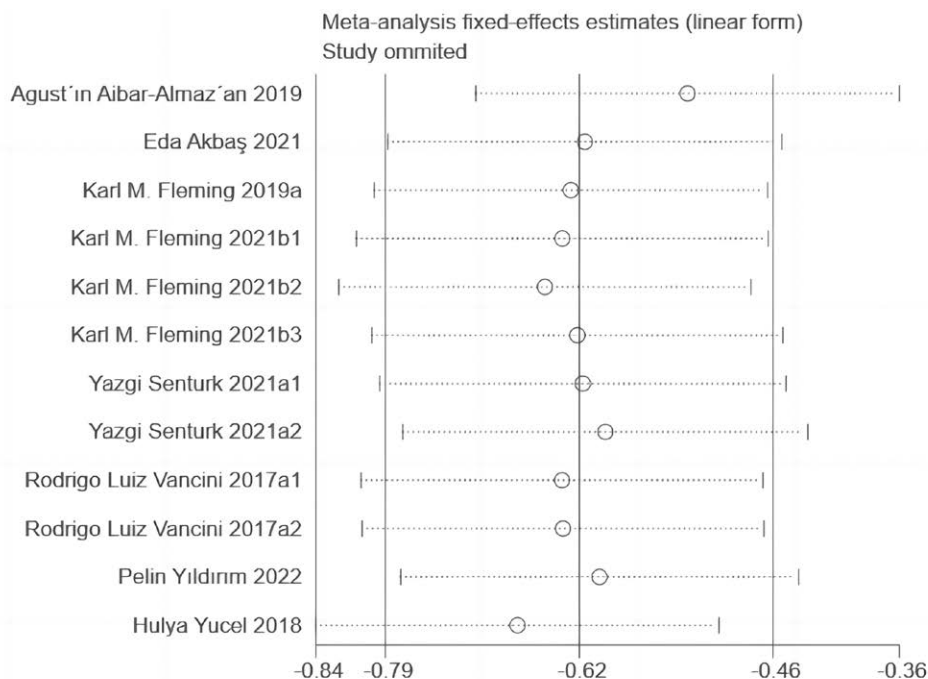


Figure 8. Sensitivity analyses illustrating the effects of the Pilates exercise on anxiety symptoms in female patients.

sensitivity analyses were performed. Furthermore, no heterogeneity was found in the 8 studies included ($I^2 = 16.1\%$; $P = .286$) in the Pilates intervention for anxiety in female patients; the sensitivity analysis was still carried out to ensure data accuracy and stability. Sensitivity analyses demonstrated that each of the included studies had a high degree of agreement with the centerlines. The combined ES did not materially alter the association between the PE/PEG with depression and anxiety despite the exclusion of individual studies, suggesting that the meta-analysis had excellent stability. The sensitivity analyses

for depression and anxiety are displayed in Figures 7 and 8, respectively.

3.8. Analysis of publication bias

Figure 9 illustrates the funnel chart of the effect of the PE/PEG on depression symptoms in female patients. The Egger and Begg tests also indicated no significant publication bias (Egger test: $P = .820$, $t = -0.23$; Begg test: $P = .807$, $z = 0.24$). Figure 10 displays a funnel chart of the effect of the PE/PEG

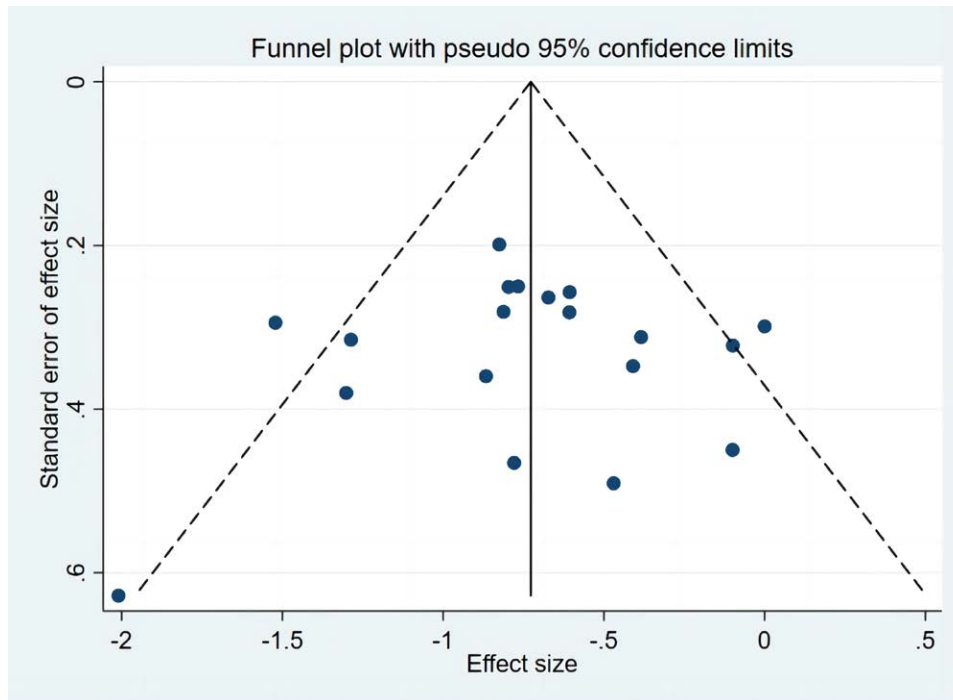


Figure 9. Funnel plot of publication bias for the effect of the Pilates exercise on depression symptoms in female patients.

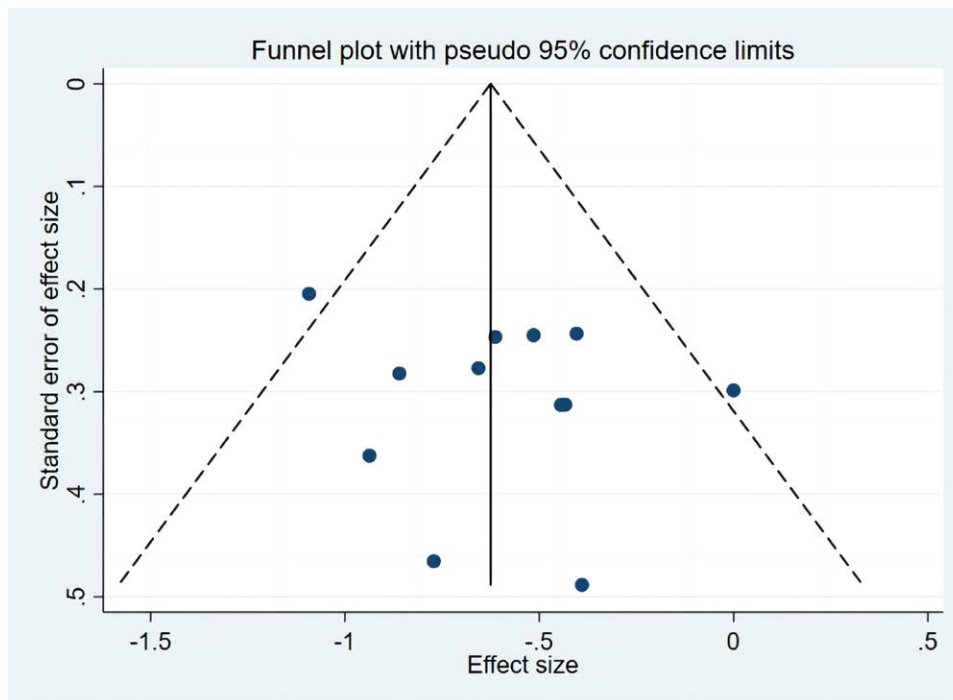


Figure 10. Funnel plot of publication bias for the effect of the Pilates exercise on anxiety symptoms in female patients.

on anxiety symptoms in female patients. Similarly, the results of Egger and Begg tests also showed no significant publication bias (Egger test: $P = .394$, $t = 0.89$; Begg test: $P = .0891$, $z = -0.14$).

4. Discussion

This systematic review and meta-analysis aimed to examine the evidence from RCT studies examining the effects of PE/PEG on

female patients with depression and anxiety in order to identify appropriate exercise prescriptions. Eighteen RCTs found moderate evidence of short-term improvement in the severity of symptoms of depression and anxiety, with 19 studies using depression as an outcome indicator and 12 studies using anxiety as an outcome indicator. The findings showed that PE/PEGs (e.g., mat Pilates, home Pilates, clinical Pilates, Pilates, and aerobic exercise) reduced depression and anxiety in female patients. This suggests that healthcare professionals can integrate PE/

PEGs with routine medical care to optimize the treatment of depression and anxiety symptoms in female patients. According to the GRADE criteria, the quality of evidence and the grade of recommendation of the 18 included articles were moderate. However, a high level of randomized controlled studies is still needed.

Some of the results of this review are consistent with the results of other recently published systematic reviews examining the therapeutic effects of PE/PEG in relieving patients with multiple sclerosis.^[59,60] This study showed that PE/PEG was beneficial for patients with multiple sclerosis; however, the quality of the included studies was low and the risk of bias of the included trials was not analyzed. Meanwhile, we found that PE/PEG was a better intervention for the middle-aged and elderly female population, and our study concluded that the longer the duration of Pilates training, the better the effect. This adds confidence to the alleviation of depression and anxiety in middle-aged and older women, and Pilates may be an alternative complementary therapy that can be recommended to this population when patients are more resistant to medication, but at the same time, we observed that it seems to be less useful for patients with metabolic disorders, and that although the combination of the findings showed efficacy, it did not reach statistical significance.

Specifically, the ESs ranged from -0.90 to -0.52 ($P < .01$) for depression and -0.78 to -0.36 ($P < .01$) for anxiety. In addition, no RCT studies reported adverse events, so the safety of Pilates in female patients could not be assessed. However, a previous systematic review of Pilates interventions in other settings did not find evidence of serious adverse events.

As for the role of Pilates in relieving anxiety and depression, previous studies have suggested that it may be the activation of the AMPK signaling pathway in patients after regular exercise, leading to the release of the enkephalinase enzyme, which is known to stimulate the body and mind to be in a state of relaxation and pleasure, and that the strength of the immune system is strengthened by the stimulation of endorphins. Unlike other sports with higher intensity and shorter duration, Pilates sports are characterized by lower intensity and longer duration, a feature that is in line with the physiological norms of endorphin release, and long, continuous, medium-intensity exercise and deep breathing are also conditions for the secretion of cerebral endorphins, while another feature of Pilates sports is the deep coordination of respiration and movement, and the process of the exercise contains a large number of deep-breathing movements. Pilates is also characterized by a deep coordination of breathing and movement. Endorphins are secreted when prolonged exercise depletes glycogen from the muscles, leaving only oxygen. In addition, Pilates is practised in a quiet room with other people, which not only provides a quiet environment, but also provides the instructor with a form of social support that enables the patient to feel, sense and accept help and support from others. Pilates is usually performed by more than 1 person at the same time, and the establishment and maintenance of relationships during exercise not only promotes adherence to exercise behaviors, but also provides a variety of social support to help individuals solve various psychological and behavioral problems and promote mental health.

In summary, we found that PE/PEG can alleviate symptoms of depression and anxiety in female patients and have a positive effect on mental health. However, despite these advantages, there are some limitations to this study that need to be acknowledged. Firstly, due to the small number of participants and the non-uniformity of the units of results, this study cannot be considered universally acceptable. Secondly, there is a lack of data on adverse effects and it is uncertain whether the results of this study can be directly applied to clinical patients. Finally, the intervention programme was also not uniform, ranging from a single PE/PEG programme to a combination of Pilates and other types of Pilates programmes, which may have affected the results of the study.

5. Conclusions

This meta-analysis has further strengthened the evidence for the positive effects of PE/PEG on depression and anxiety symptoms in female patients. Pilates is a feasible strategy for female patients with depression or anxiety that can lead to improvements in their physical fitness and body functions, and it might be helpful for decreasing negative emotions (e.g., depression and anxiety symptoms). Mat Pilates and Home Pilates exhibited the highest probability, is becoming the commonest intervention in female patients, and clinical Pilates may be biased in favor of clinical populations. It is possible that in the present situation, Pilates combined with aerobic exercise may have a positive impact on female patients' depression and anxiety.

Author contributions

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 Writing – review & editing: Lili Gao, Wenbing Yu.

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