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Effects of Pilates Exercise on Women's Health Outcomes: An Umbrella Review with Meta-Analysis

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Abstract **BACKGROUND:** Despite Pilates exercise's widespread adoption in health promotion, variations in implementation protocols and targeted health outcomes have resulted in fragmented evidence. A synthesis of existing evidence is required to establish evidence-based protocols and its validated effects for women's health outcomes. **PURPOSE:** The purpose of this review was to evaluate the characteristics of Pilates exercise interventions, evaluate the methodological quality of existing systematic reviews, estimate Pilates exercise effects on diverse health outcomes, and discuss future Pilates exercise research. **METHODS:** Two independent researchers conducted a literature search across four databases, following the PRISMA guidelines. After the screening process, eight systematic reviews were included. Additionally, the researchers investigated each systemic review's included independent studies (n = 40). Quality of appraisal was conducted using the AMSTAR 2 tool, followed by a meta-analysis performed with R software. **RESULTS:** Analysis of FITT revealed substantial heterogeneity in Pilates exercise interventions. No study adopted theoretical frameworks for guiding intervention development and implementation. Methodological quality assessment rated all systematic reviews low, primarily due to inadequate statistical approaches and insufficient analysis of between-study heterogeneity. There were significant improvements in flexibility (Cohen's d = 0.74, 95% CI [0.32, 1.16]), cardiorespiratory fitness (Cohen's d = 0.95, 95% CI [0.41, 1.48]), and labor outcomes (pain: Cohen's d = -1.29, 95% CI [-1.86, 0.72]; delivery time: Cohen's d = -0.42, 95% CI [-0.77, -0.08]). **CONCLUSION:** There is a critical need to develop standardized Pilates exercise protocols tailored to women's specific health outcomes.

Keywords: *exercise, female, health promotion, meta-synthesis, Pilates*

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1. Introduction

Pilates exercise is a comprehensive physical conditioning method that emphasizes core stability, muscular strength, flexibility, postural alignment, and controlled breathing [1] Its biomechanical foundation is grounded in principles of human movement science; each exercise is purposefully designed to improve neuromuscular efficiency and joint mechanics, thereby promoting functional movement patterns and minimizing injury risk [2]. Moreover, the integration of biomechanical precision and mindful awareness underlies its use in both physical rehabilitation and psychological well-being [3,4,5]This holistic approach suggests Pilates exercise holds promise as a versatile intervention adaptable to diverse population and fitness levels, including for addressing the complex health needs specific to women.

Globally, women encounter distinct and often disproportionate health challenges arising from a complex interplay of biological determinants, sociocultural dynamics, and systematic inequities [6]. Biological factors, including the reproductive life cycle (e.g., menarche, pregnancy, postpartum, menopause), hormonal fluctuations, and sex-specific predispositions, contribute to unique health profiles. Women experience higher rates of certain conditions such as depression, anxiety disorders, autoimmune diseases, osteoporosis, and specific musculoskeletal issues such as low back pain [7]. Sociocultural factors, including unequal power relationships, restrictive gender norms limiting education and employment, an overwhelming focus on reproductive roles, and pervasive gender-based violence, further compound these vulnerabilities [8,9]. Systemic issues, such as gender bias in medical research and healthcare delivery, diagnostic delays for conditions like cardiovascular disease and cancer, and socioeconomic disadvantages, create additional barriers to optimal health [6]. These challenges are not static but accumulate and interact across a woman's lifespan; early life exposures and cumulative stressors significantly shape long-term health trajectories, influencing risks for chronic diseases and functional decline in later life [10]. The constant pressure on women to navigate these biological, social, and systemic challenges highlights a critical need for holistic health interventions that address both physical and mental well-being.

The recognition of Pilates exercise potential benefits, combined with its increasing global popularity, has drawn considerable scholarly interest, resulting in an exponential rise in studies investigating Pilates exercise-based interventions for diverse women's health outcomes (Figure 1). In response to the numerous reports of Pilate exercise-based interventions in the domain of physical activity research, there is a clear need for a comprehensive synthesis and critical appraisal of the existing evidence base. Umbrella reviews provide a methodological solution by systematically synthesizing evidence from multiple systematic reviews and meta-analyses, offering a high-level overview of the existing knowledge, assessing the consistency and quality of evidence, and identifying robust findings and persistent research gaps [11]. Therefore, this umbrella review was conducted to synthesize the breadth of evidence from existing systematic reviews and meta-analyses regarding the effects of Pilates exercises across a spectrum of women's health outcomes. A key aspect of this review involves not only summarizing what is known about the effectiveness of Pilates exercise but also evaluating how this knowledge has been generated. By systematically mapping the characteristics of interventions alongside quantifiable health impacts across existing literature reviews, this study aimed to reveal patterns in research methodology and highlight areas needing more rigorous investigation, thereby informing future research and evidence-based practice guidelines.

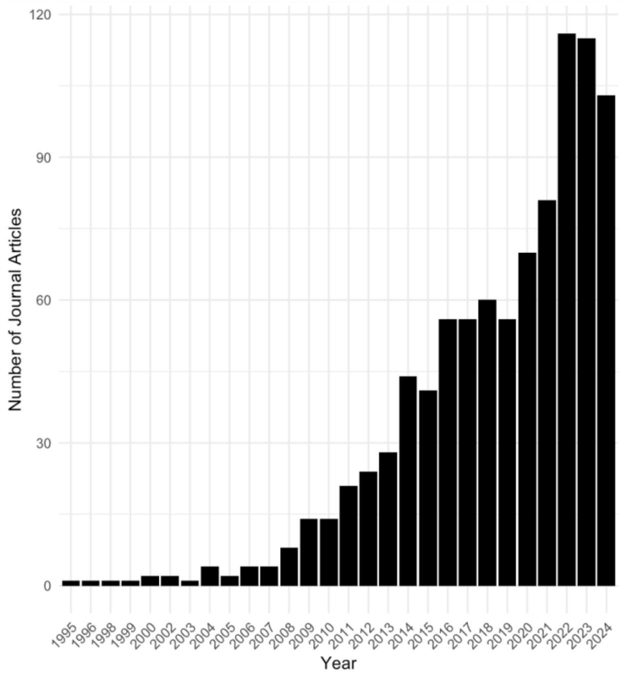

Figure 1. Trends of Pilates exercise research

Specifically, this umbrella review addressed the following research questions: 1) What are the characteristics (i.e., experimental design, implementation strategies, theoretical frameworks) of Pilates exercise interventions targeting women's health outcomes as reported in existing systematic reviews and meta-analyses?; 2) what is the synthesized evidence from these reviews on the quantifiable health impacts of Pilates exercise interventions across various physiological and psychological domains relevant to women's health?'; and 3) what are the key strengths and limitations in the current body of systematic review evidence on Pilates exercise for women's health?

2. Methods

An umbrella review is a rigorous methodological approach that synthesizes and critically evaluates evidence from multiple systematic reviews into a comprehensive analytical framework [12]. This methodology allows researchers to systematically compare, contrast, and assess the quality, consistency, and strength of conclusions across multiple reviews, thereby producing a higher-level synthesis of the existing results [12]. Given the heterogeneity in reported effects of Pilates exercises on diverse health outcomes [13], we applied a focused analytical lens on women in the general population and their associated health outcomes. To strengthen the analytical rigor of this review, we conducted a detailed examination of the primary studies included within each systematic review. This additional layer of analysis was expected to enable the calculation of pooled effect sizes while accounting for inter-study heterogeneity, ultimately providing deeper insights into the effectiveness of Pilates exercise interventions and the variability of their outcomes.

2.1. Literature Search Strategy

Table 1. Developed search queries

PubMed #1 ("exercise movement techniques"[MeSH Terms] OR "exercise movement techniques"[MeSH Terms] OR "exercise movement techniques"[MeSH Terms] OR "exercise movement techniques"[MeSH Terms] OR "exercise movement techniques"[MeSH Terms] OR "exercise movement techniques"[MeSH Terms] OR "exercise movement techniques"[MeSH Terms] OR "pilates"[Title/Abstract] #2 "women"[Title/Abstract] OR "woman"[Title/Abstract] OR "female"[Title/Abstract] OR "females"[Title/Abstract] #3 #1 AND #2 AND (systematic review[Filter])
Cochrane Library #1 ((Exercise Movement Technics) OR (Movement Techniques) OR (Exercise Pilates Training) OR (Pilates Based Exercises) OR (Pilates-Based Exercise) OR (Exercises, Pilates-Based) OR (Training, Pilates)) OR "pilates" #2 (women:ti,ab,kw) OR (woman:ti,ab,kw) OR (female:ti,ab,kw) OR (females:ti,ab,kw) #3 #1 AND #2 in Cochrane Reviews
CINAHL (MH pilates OR pilates) AND (women OR woman OR female OR females) AND (review OR reviews) in Peer Reviewed, Academic Journals
SPORTDiscus (MH pilates OR pilates) AND (women OR woman OR female OR females) AND (review OR reviews) in Peer Reviewed, Academic Journals

A literature search was conducted across four major electronic databases: PubMed, Cochrane Library, CINAHL, and SPORTDiscus. Citation management and organization were facilitated through the integration of Zotero reference management software and Microsoft spreadsheet application. The development of search strategies benefited from a collaborative partnership between a research team member, who serves as an instructor (SC) for the graduate-level course "*Systematic Review and Meta-Analysis*," and a specialized Kinesiology librarian at the university. This expert collaboration ensured the construction of database-specific search queries optimized for each platform's unique search workflow [12]. The search strategy incorporated both controlled vocabulary (i.e., MeSH terms) for "*Pilates*" and supplementary keywords including "*women*" and "*female*" to ensure comprehensive retrieval of pertinent literature. The detailed search syntax and Boolean operators employed for each database are systematically documented in Table 1. The definitive literature search was concluded on August 27, 2024.

2.2. Study Selection Process

The study selection criteria were established using the PICO (Population, Intervention, Comparison, Outcome) framework [14]. The target population was specifically defined as adult women aged between 18 and 65 years engaging in Pilates exercise. This age range delimitation excludes pediatric and adolescent populations, where developmental factors significantly influence health outcomes, and older adults, where age-related conditions and comorbidities may confound results. This investigation focused specifically on Pilates exercise interventions designed to enhance health and wellness in adult women without acute or chronic illnesses, excluding studies primarily aimed at medical treatment. This limited scope allows for a more focused examination of Pilates' effectiveness in health promotion rather than treatment purposes. Only systematic reviews and meta-analyses were included to facilitate the synthesis of existing scientific evidence. Studies were excluded if they met any of the following criteria: 1) involved participants currently undergoing active medical treatment or acute rehabilitation, 2) examined mixed-modality exercise interventions that extended beyond pure Pilates exercise, 3) lacked health-related outcome measures including health-related quality of life, physical function, fitness, body composition, or psychological well-being, or 4) were published in languages other than English.

The initial screening process was conducted independently by two researchers (Author 1, Author 2) who evaluated titles and abstracts for relevance. Full-text articles were retrieved when abstracts provided insufficient information for eligibility determination. Any disagreements between two authors were resolved through collaborative discussion to reach consensus. The final selection of studies was determined through independent full-text review by two researchers, applying the predetermined eligibility and exclusion criteria with systematic rigor (Figure 2).

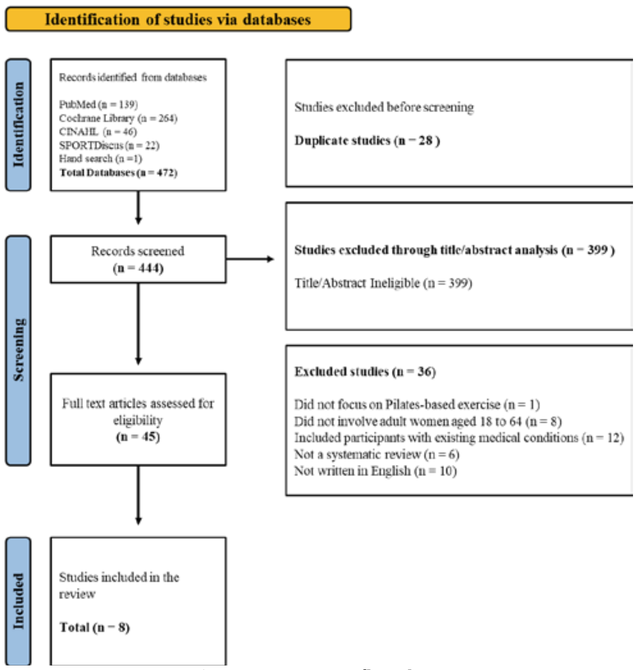

Figure 2. PRISMA flowchart

2.3. Data Extraction Process

A hierarchical two-tiered approach was employed for data extraction, systematically analyzing characteristics at the review level as well as components of individual studies. The first tier focused on the analysis of the included systematic reviews, encompassing bibliometric information, review methodology, number of included individual studies, key findings regarding Pilates exercise effects on women's health outcomes, and methodological considerations including protocol variations, study design heterogeneity, and inconsistent outcome measurement. The second tier involved a detailed examination of all individual studies included in the selected systematic reviews. This analysis encompassed study characteristics (e.g., purpose, design, setting), women population demographics (e.g., sample size, participant characteristics, age range), theoretical frameworks, intervention details (e.g., instructor qualifications, Frequency/ Intensity/ Time/Time characteristics, delivery methods), and outcome assessment parameters, statistical approaches, and reported findings. This structured approach ensured comprehensive data capture while maintaining systematic organization of extracted information.

2.4. Assessment of Methodological Quality of Included Systematic Reviews

The methodological quality assessment was conducted using AMSTAR 2 (A Measurement Tool to Assess Systematic Reviews, version 2), a validated instrument for evaluating systematic reviews of healthcare interventions incorporating both randomized and non-randomized studies [15]. This tool comprises 16 items examining critical methodological aspects, including protocol registration, search strategy, study selection processes, data extraction protocols, risk of bias assessment, and meta-analytical methods. AMSTAR 2's evaluation framework utilizes seven critical and nine non-critical domains, each assessed on a three-point scale (i.e., "Yes," "Partial Yes," or "No"). Moving beyond its predecessor's numerical scoring system, AMSTAR 2 employs a nuanced approach that evaluates overall confidence in review findings based on performance across critical and non-critical domains, yielding four confidence levels: High, moderate, low, or critically low. For this review, two authors conducted domain-specific assessments, resolved discrepancies through consensus discussions, and applied standardized decision rules to determine final quality ratings.

2.5. Quantitative Synthesis

For continuous outcomes, means and standard deviations were extracted. A random-effect model was employed for meta-analysis, as Pilates exercise interventions included diverse age groups and varied protocols and experimental designs, requiring a model that accommodates this variability. Effect sizes were calculated as standardized mean differences (i.e., Cohen's *d*) with 95% confidence intervals (CI), with statistical significance set at $p < 0.05$. Following Cohen's criteria (1992), effect sizes were categorized as small (< 0.50), moderate (0.50 – 0.79), or large (> 0.80) [16]. Heterogeneity between studies was quantified using the I^2 statistics with values of 0 – 25% indicating low heterogeneity, 25 – 50% moderate heterogeneity, and > 50% moderate to high heterogeneity, and τ^2 statistic [17].

3. Results

3.1. Included Systematic Reviews and Their Analyzed Individual Studies

This umbrella review with meta-analysis encompassed eight systematic reviews (Table 2), collectively analyzing their included individual studies (N = 45) (Appendix A). Across these studies, a total of five studies were excluded due to non-English language (n = 3), and inability to retrieve the original paper (n = 2). Finally, a total of 40 individual studies were included in the additional analysis.

3.2. Quality of the Studies

The methodological quality assessment using AMSTAR 2 revealed significant limitations across included systematic reviews (Table 3), with an inter-rater agreement of 0.80 between two authors. While basic research design elements were adequately addressed (i.e., research question formulation, duplicate study selection, and data extraction), critical methodological domains showed substantial weaknesses. Fewer than 30% of reviews met criteria for comprehensive literature search strategy, excluded studies documentation, appropriate statistical methods, risk of bias consideration, and publication bias analysis. None of the reviews adequately addressed publication bias or its potential impact on findings, resulting in critically low overall quality ratings. Among the systematic reviews conducting meta-analyses [18,19,20,21,22,23], only 16.7% employed appropriate statistical methods, and 33.3% accounted for risk of bias. Notably, 75% failed to incorporate risk of bias assessments in their results interpretation. Overall, 81.3% of AMSTAR 2 criteria (13 out of 16 items) showed compliance rates of 50% or below.

3.3. Characteristics of Pilates Exercise Interventions

Analysis of 40 Pilates intervention studies in women aged 18-65 revealed predominant use of randomized controlled trials (RCTs) (n = 35, 87.5%) with sample sizes of 11-105 participants. Most studies (n = 30, 85.7%) employed parallel design comparing experimental and control groups. Intervention characteristics showed consistent session frequency (2.3±0.76 times/week, Coefficient of Variation (CV) = 33%) and duration (56±10.8 minutes, CV = 19.2%), though program length varied substantially (11.9±8.4 weeks, CV = 71.0%, Range: 4-48 weeks). Mat-based Pilates dominated (n = 31, 77.5%), followed by equipment-based (n = 6, 15.0%) and combined approaches (n = 1, 2.5%). Two studies did not report any type of Pilates exercise they used [24,25]. Exercise intensity was reported in 42.5% of studies (n = 17), categorized as low (n = 6, 15%) or moderate (n = 11, 27.5%), with 30% (n = 12) providing precise measurements via tools including the Borg RPE scale.

Instructor qualifications were notably underreported, with only one study mentioning "*ample experience*" without details [26]. It also revealed substantial diversity in targeted health outcomes, with 18 outcomes reported across the studies (n = 31, 77.5 %) and 59 appearing in single studies (n = 27, 67.5%). A trend analysis demonstrated an evolution in research focus: Early studies (2007-2012) emphasized rehabilitation and physical function outcomes (i.e., muscle strength, posture, pain management); the intermediate period (2013-2017) expanded to include quality of life and blood lipid profiles; and recent years (2017-2024) introduced labor-related outcomes.

The analysis revealed a lack of theoretical evidence in the Pilates exercise intervention literature: none of the included systematic reviews and their included individual studies examined theoretical frameworks underlying intervention development and implementation.

3.4. Pooled Effect Sizes of the Reported Health Impacts

The meta-analysis was conducted to evaluate Pilates exercise effects across diverse health outcomes, including physical health (i.e., pain, blood lipids, bone mineral density), function and mobility (i.e., 6-min walk test, sit and reach, timed up and go), body composition (i.e., body fat percentage, BMI, body weight), perceived quality of life (i.e., SF-36), pain (i.e., VAS) and labor/postpartum-related variables. The analysis incorporated baseline and post-intervention mean differences and standard deviations, excluding follow-up results due to inconsistent reporting across studies. Detailed results of the meta-analysis are presented in Table 4. The estimated effects of Pilates exercise interventions on women's health outcomes included significant improvements in flexibility (Cohen's *d* = 0.74, 95% CI [0.32, 1.16]) and cardiorespiratory fitness (Cohen's *d* = 0.95, 95% CI [0.41, 1.48]). In addition, Pilates exercise showed significant effects in reducing labor pain (Cohen's *d* = -1.29, 95% CI [-1.86, -0.72]) and shortening labor time (Cohen's *d* = -0.42, 95% CI [-0.77, -0.08]). Conversely, no statistically significant pooled effects were found in pain, quality of life, body composition metrics, blood lipids, and agility. Nevertheless, Pilates exercise demonstrated potential effects on systolic blood pressure and weight gain during pregnancy with high heterogeneity.

Table 2. Included systematic reviews (*N* = 8)

Author(s)	Year	Published journal	Purpose	Selected databases	*N* of the included studies	Main findings
Peruzzolo de Almeida et al.	2024	*Quality of Life Research*	To verify the effects of Pilates exercises on health-related quality of life in postmenopausal women.	PubMed, Embase, CENTRAL, CINAHL, Web of Science, LILACS, SportDiscus, Scielo, and PEDro	11	Statistically significant pooled effect sizes were observed for pain, physical functioning, social functioning, role physical, and role emotional.
Baradwan et al.	2024	*Women & Health*	To provide a comprehensive summary of the evidence from studies that have assessed the effects of Pilates exercise on delivery outcomes.	PubMed, Scopus, Cochrane Library, and ISI Web of Science.	7	Statistically significant pooled effect sizes were shown in the rate of vaginal delivery, labor duration, incidence of episiotomy, the need for epidural analgesia, and APGAR scores.
de Souza Feraz et al.	2023	*Journal of Bodywork and Movement Therapies*	To assess the efficacy of the Pilates method in comparison to prenatal care on the control of lower back pain in pregnant women.	MEDLINE, EMBASE, LILACS, CINAHL, PEDro, SPORTDiscus, and Cochrane Library	2	Statistically significant pooled effect sizes were observed for back pain.
Zaman et al.	2023	*Medicine*	To collect evidence about Pilates exercise effects on maternal and neonatal outcomes and obstetric outcomes in pregnant women.	PubMed, Clinical Key, Cochrane Library, Scopus, Embase, and Web of Science	13	Statistically significant pooled effect sizes were observed for two types of delivery (Vaginal, Cesarean), Duration of the Active Phase of Labor, Duration of the Second Stage of Labor, Total duration of labor, Body weight gain during pregnancy, and APGAR score at 1 minute.
de Oliveira et al.	2022	*Journal of Geriatric Physical Therapy*	To conduct a systematic review and meta-analysis of randomized controlled trials examining the effect of Pilates on Bone Mineral Density.	PubMed, Web of Science, LILACS, SciELO, the Cochrane Library, and PEDro	3	No statistically significant pooled effect sizes were observed for bone mineral density at the lumbar spine, total hip, and femoral neck.
Lemos et al.	2019	*Journal of Bodywork & Movement Therapies*	To evaluate the response of the Pilates method in the function of the pelvic floor muscles in healthy women.	Pubmed, SciELO, LILACS, MEDLINE, Web OF Science and CINAHL	2	No significant pooled effect sizes were demonstrated in pelvic floor muscle function.
Schmit et al.	2016	*Fisioterapia e Pesquisa*	To verify the level of scientific evidence of the influence of Pilates method on the postural alignment in women.	BIREME, EMBASE, PEDro, PubMed, Scielo, Science Direct,SCOPUS, and Web of Science.	4	No significant effects were found for postural alignment due to the conflicting results of the included studies.
Mazzarino et al.	2015	*Archives of Physical Medicine and Rehabilitation*	To analyze the benefits of Pilates on health outcomes in women.	CINAHL, MEDLINE, PubMed, Science Direct, SPORTDiscus, PEDro, Cochrane, and Web of Science.	13	Significant effects were observed for pain reduction, improvement in low extremity endurance, quality of life, functional capacity, reduction in number of falls, range of motion for trunk flexion.

Table 3. Quality of appraisal results (*N* = 8)

Systematic Reviews	Research Question Included PICO	Review methods established prior to review	Explanation of study design selection	Comprehensive Literature search strategy	Study selection performed in duplicate	Data extraction performed in duplicate	List of excluded studies with justification	Describe studies in adequate detail	Satisfactory technique for assessing RoB	Report Sources of funding	Use Appropriate Methods for statistical combination of results	Account for potential RoB in individual studies on meta-analysis	Account for RoB in individual studies when interpreting results	Explanation for and discussion of heterogeneity in results	Investigate publication bias and discuss impact	Reported any conflict of interest	No. of critical domains weaknesses	Final rating
de Souza Feraz et al., 2023	Yes	Partial Yes	Yes	No	Yes	Yes	No	Partial Yes	Partial Yes	No	No	Yes	Yes	No	No	Yes	4	Critically low
Peruzzolo de Almeida et al., 2024	Yes	Partial Yes	No	No	Yes	Yes	No	Partial Yes	Partial Yes	No	Yes	Yes	Yes	Yes	No	Yes	3	Critically low
Schmit et al. 2016	Yes	Partial Yes	No	Partial yes	Yes	Yes	No	Partial Yes	No	No	N/A	N/A	No	No	N/A	No	3	Critically low
de Oliveira et al., 2022	Yes	Partial Yes	No	Partial yes	Yes	No	No	Partial Yes	Partial Yes	No	No	No	No	No	No	No	4	Critically low
Zaman et al., 2023	Yes	Partial Yes	No	No	No	No	No	Partial Yes	Partial Yes	No	No	No	No	No	No	No	5	Critically low
Mazzarino et al., 2015	Yes	Partial Yes	No	No	Yes	Yes	No	Partial Yes	Partial Yes	No	N/A	N/A	No	Yes	N/A	No	3	Critically low
Lemos et al., 2019	Yes	Partial Yes	No	No	Yes	Yes	Yes	Partial Yes	Partial Yes	No	No	No	No	No	No	Yes	4	Critically low
Baradwan et al., 2024	Yes	Partial Yes	No	No	Yes	Yes	No	Partial Yes	Partial Yes	No	No	No	No	No	No	Yes	5	Critically low

Table 4. Meta-analysis results

Outcome	Study	Sample size (Pilates/Control)	Cohen's *d* [95% CI]	Weight (%)	Heterogeneity
Pain (VAS score)	Sonmezer et al. (2020)	20/20	0.24 [-0.38, 0.86]	41%	I^2 = 96%, τ^2 = 3.85, $p < 0.001$
	Angin et al. (2015)	22/19	0.94 [0.29, 1.59]	37.60%	
	Küçükçakir et al. (2013)	35/30	4.02 [3.15, 4.88]	21.40%	
	Total	77/69	1.71 [-0.54, 3.97]	100%	
General Health (QoL_SF36 score)	Pucci et al. (2020)	13/14	-0.61 [-1.38, 0.17]	21.30%	I^2 = 81.9%, τ^2 = 0.61, $p <$ 0.001
	Liposcki et al. (2019)	9/11	0.64 [-0.27, 1.55]	15.50%	
	Oliveira et al. (2015)	16/16	1.32 [0.76, 1.88]	40.50%	
	Küçükçakir et al. (2013)	30/30	1.09 [0.34, 1.84]	22.70%	
	Total	68/71	0.63 [-0.22, 1.48]	100%	
Mental Health (QoL_SF36's subscore)	Pucci et al. (2020)	13/14	-0.33 [-1.09, 0.43]	23.8 %	I^2 = 52.9%, τ^2 = 0.16, $p < 0.05$
	Liposcki et al. (2019)	9/11	0.83 [-0.10, 1.76]	19.2 %	
	Oliveira et al. (2015)	16/16	0.93 [0.20, 1.67]	24.6 %	
	Küçükçakir et al. (2013)	30/30	0.53 [0.01, 1.04]	32.4 %	
	Total	68/71	0.48 [-0.05, 1.01]	100 %	
Systolic Blood Pressure (mmHg)	Rodriguez-Diaz et al. (2017)	50/55	-1.34 [-1.76, -0.91]	52.8 %	I^2 = 79.9%, τ^2 = 0.26, $p < 0.05$
	Marinda et al. (2013)	25/25	-0.53 [-1.10, 0.03]	47.2 %	
	Total	75/80	-0.96 [-1.74, -0.17]	100%	
Diastolic Blood Pressure (mmHg)	Rodriguez-Diaz et al. (2017)	50/55	-1.06 [-1.47, -0.65]	50.9 %	I^2 = 93.9%, τ^2 = 0.97, $p <$ 0.0001
	Marinda et al. (2013)	25/25	0.37 [-0.19, 0.93]	49.1 %	
	Total	75/80	-0.36 [-1.77, 1.05]	100%	
Total Cholesterol (mg/dL)	Hyun et al. (2020)	9/7	-0.31 [-1.31, 0.68]	22.9 %	I^2 = 10.7%, τ^2 = 0.05, p = 0.33
	Kim et al. (2022)	8/8	-0.73 [-1.75, 0.29]	21.9 %	
	Marinda et al. (2013)	25/25	0.12 [-0.43, 0.67]	55.2 %	
	Total	42/40	-0.17 [-0.68, 0.35]	100%	
Triglycerides (mg/dL)	Hyun et al. (2020)	9/7	-0.08 [-1.07, 0.91]	19.5 %	I^2 = 0%, τ^2 = 0, p = 0.58
	Kim et al. (2022)	8/8	-0.63 [-1.65, 0.38]	18.6 %	
	Marinda et al. (2013)	25/25	-0.01 [-0.57, 0.54]	61.9 %	
	Total	42/40	-0.14 [-0.58, 0.29]	100%	
High Density Lipoprotein (mg/dL)	Hyun et al. (2020)	9/7	0.14 [-0.85, 1.13]	49.9 %	I^2 = 0%, τ^2 = 0, p = 0.83
	Kim et al. (2022)	8/8	0.29 [-0.69, 1.28]	50.1 %	
	Total	17/15	0.22 [-0.48, 0.91]	100%	
Body Weight (Pounds)	Junges et al. (2012)	22/19	-0.19 [-0.81, 0.42]	27.1 %	I^2 = 0%, τ^2 = 0, p = 0.42
	Cakmakci (2011)	34/27	-0.30 [-0.81, 0.21]	39.7 %	
	Fourie et al. (2013)	25/25	0.19 [-0.37, 0.74]	33.2 %	
	Total	81/71	-0.11 [-0.43, 0.21]	100%	
Body Mass Index	Junges et al. (2012)	22/19	-0.36 [-0.98, 0.26]	26.9 %	I^2 = 0%, τ^2 = 0, p = 0.51
	Cakmakci (2011)	34/27	-0.38 [-0.89, 0.13]	39.6 %	
	Fourie et al. (2013)	25/25	0.03 [-0.53, 0.58]	33.5 %	
	Total	81/71	-0.24 [-0.56, 0.08]	100 %	
Fat Percentage (%)	Junges et al. (2012)	22/19	-0.53 [-1.15, 0.10]	32.5 %	I^2 = 87.2 %, τ^2 = 0.56, $p <$ 0.0001
	Cakmakci (2011)	34/27	0.96 [0.42, 1.49]	33.9 %	
	Fourie et al. (2013)	25/25	-0.30 [-0.86, 0.26]	33.6 %	

	Total	81/71	0.05 [-0.86, 0.96]	100%	
Cardiorespiratory Fitness (6-Minute Walking Test)	Angin et al. (2015)	22/19	0.51 [-0.11, 1.14]	33.2 %	I^2 = 54.2 %, τ^2 = 0.12, p = 0.11
	Küçükçakir et al. (2013)	30/30	0.89 [0.36, 1.42]	37.9 %	
	Eyigor et al. (2010)	27/15	1.52 [0.80, 2.24]	29.0 %	
	Total	79/64	0.95 [0.41, 1.48]	100%	
Agility (Timed Up and Go Test)	Oliveira. (2015)	16/16	-1.45 [-2.24, -0.66]	46.7 %	I^2 = 80.4 %, τ^2 = 0.50, $p < 0.05$
	Gildenhuys et al. (2013)	25/25	-0.34 [-0.89, 0.22]	53.3 %	
	Total	41/41	-0.86 [-1.95, 0.23]	100%	
Flexibility (Sit and Reach Test)	Sinzato et al. (2013)	14/19	0.73 [0.01, 1.44]	34.9 %	I^2 = 0.0 %, τ^2 = 0, p = 0.96
	Cakmakci (2011)	34/27	0.75 [0.23, 1.27]	65.1 %	
	Total	48/46	0.74 [0.32, 1.16]	100 %	
Body Weight During Pregnancy (Pounds)	Hyun et al. (2020)	9/7	0.18 [-0.81, 1.17]	11.8 %	I^2 = 0.0 %, τ^2 = 0, p = 0.61
	Hyun et al. (2021)	7/7	0.00 [-1.05, 1.05]	10.5 %	
	Rodriguez-Diaz et al. (2017)	50/55	-0.31 [-0.69, 0.08]	77.7 %	
	Total	66/69	-0.22 [-0.56, 0.12]	100%	
Total Body Weight Gain During Pregnancy (Pounds)	Atakan et al. (2021)	21/22	-0.42 [-1.03, 0.19]	31.3 %	I^2 = 77.2 %, τ^2 = 0.23, $p < 0.05$
	Feria-Ramírez et al. (2021)	24/48	-0.67 [-1.56, 0.21]	15.0 %	
	Yaman et al. (2020)	26/57	-0.36 [-0.82, 0.11]	53.7 %	
	Total	71/127	-0.42 [-0.77, -0.08]	100%	
Labor pain (VAS score)	Atakan et al. (2021)	21/22	-1.66 [-2.36, -0.96]	38.4 %	I^2 = 52.2 %, τ^2 = 0.09, p = 0.15
	Ghandali (2021)	51/52	-1.06 [-1.47, -0.65]	61.6 %	
	Total	72/74	-1.29 [-1.86, -0.72]	100 %	
Labor time (minutes)	Atakan et al. (2021)	21/22	-0.42 [-1.03, 0.19]	31.3 %	I^2 = 0.0 %, τ^2 = 0, p = 0.83
	Mazzarino et al. (2022)	11/10	-0.67 [-1.56, 0.21]	15.0 %	
	Yaman et al. (2020)	26/57	-0.36 [-0.82, 0.11]	53.7 %	
	Total	58/88	-0.42 [-0.77, -0.08]	100%	

4. Discussion

This umbrella review identified methodological and conceptual limitations in the existing literature on Pilates exercise interventions for women's health. Critical methodological weaknesses were evident across included systematic reviews (N = 8). While intervention characteristics showed consistency in session frequency and modality (i.e., mat-based Pilates), substantial heterogeneity was observed in program duration, intensity prescription, and outcome measures. The evolution of research priorities from physical function to broader wellness dimensions represents progress in Pilates exercise adoption, yet the absence of theoretical frameworks guiding intervention design and implementation remains a significant limitation. These findings highlight the urgent need for theoretically grounded, methodologically rigorous research to advance evidence-based Pilates exercise interventions for women's health.

Although RCTs dominated the included studies (87.5%), deeper analysis revealed significant methodological limitations beneath this apparent methodological strength. Only 17.1% of studies provided comprehensive randomization and allocation concealment protocols, while a mere 5.7% detailed blinding procedures, undermining the robustness of the reported findings [24,27]. In particular, the lack of standardized methods for prescribing and quantifying exercise intensity emerges as a particularly critical flaw in the reviewed Pilates literature [28]. Several factors may contribute to this standardization deficit. Pilates methodology inherently emphasizes control, precision, and mindful execution overachieving maximal exertion or quantifiable loads in the traditional sense. Furthermore, the field may lack validated, Pilates-specific intensity measurement tools. This absence of standardized intensity guidelines presents a significant barrier to study interpretation, replication, and clinical implementation. Future research should incorporate objective measurement tools, such as electromyography (EMG), to quantify exertion levels and muscle activation patterns, thereby establishing Pilates-specific intensity parameters. The development of validated rating scales would enable precise dose-response analyses and facilitate meaningful cross-study comparisons, ultimately advancing evidence-based recommendations for Pilates exercise prescription.

Another significant layer of methodological limitation arises from the inadequate reporting of instructor qualifications and teaching experience [29], Pilates exercise research frequently omits crucial methodological details regarding instructor expertise, a significant oversight given that proper execution of breathing and centering principles influences physiological outcomes. Proper execution, influenced by instructor cueing and correction, as evidenced by studies showing specific breathing techniques significantly increase transversus abdominis activation [30]. This evidence underscores instructors' professional expertise as a critical determinant of intervention efficacy, as proper guidance directly influences physiological outcomes. Future research must address this gap by systematically documenting instructor-related characteristics. This reporting should include details such as the specific training lineage or school (e.g., Classical, Contemporary, Polestar, Balanced Body), the level of certification achieved (e.g., Mat, Reformer, Comprehensive), total hours of training, and years of teaching experience. Where multiple instructors are involved, efforts should be made to standardize training or delivery, or at minimum, statistically account for potential instructor effects in the analysis.

The significant reduction in systolic blood pressure revealed by meta-analysis suggests Pilates exercise's potential as an alternative to conventional aerobic exercise for cardiovascular health improvement. However, the substantial heterogeneity indicates marked variability across studies, likely attributable to differences in baseline blood pressure (ranging from 105 to 135 mmHg), participant's developmental stage (i.e., pregnancy and labor), and intervention protocols (varying in equipment use and session duration from 45 to 60 minutes). The imprecise intensity measures and insufficient weekly exercise volumes relative to the American College of Sports Medicine (ACSM)'s recommended 150 minutes [31], may contribute to inter-study variability. While interventions met ACSM's minimum 8-week threshold for physiological adaptation, longer-duration studies are needed to confirm Pilates exercise's cardiovascular health benefits. Moreover, the prior study discussed that isometric exercise can reduce arterial stiffness through enhanced vascular elasticity, potentially explaining the observed differential effects [32]. Based upon this evidence, future Pilates exerciselp-= research can consider employing advanced vascular assessment tools, such as pulse wave velocity measurement via VP-1000 systems, to elucidate Pilates exercise's specific cardiovascular mechanisms and distinguish between acute hemodynamic responses and sustained vascular adaptations.

The significant improvements in flexibility highlight Pilates exercise's effects in enhancing hamstring and lumbar extensibility. This pooled effect likely stems from intervention parameters aligning with ACSM guidelines [33] for flexibility and neuromuscular training. The study contributing the highest weight (65.1%) to the meta-analysis [34] employed higher frequency (4 times/week) and progressive intensity (40-60% HRmax), key factors in promoting tissue elongation and connective tissue adaptation through neuromuscular mechanisms [35,36]. This aligns with the evidence showing eccentric training with progressive loading effectively enhances muscle fascicle length and range of motion [37]. Possibly, Pilates exercise's distinctive emphasis on active eccentric contractions may stimulate myofascial mobility and vascular perfusion—critical components for flexibility enhancement [38]. Lastly, the inclusion of specific Pilates motions (e.g., Spine Stretch, Forward Folds, Roll-Up) directly targeting sit-and-reach test requirements likely contributed to the observed large effect size. However, while the sit-and-reach test reliably measures linear static flexibility, it may not capture multi-regional or functional mobility aspects. Future research should incorporate more comprehensive assessment tools, such as Functional Movement Screening (FMS) [39], goniometric measurements (Goniometry) [40], to fully evaluate Pilates exercise's multidimensional flexibility benefits.

The observed reduction in labor pain and labor time highlights Pilates exercise as a potential non-pharmacological, low-impact modality for pregnant women. Our findings align with a previous study reporting Pilates effect in reducing the labor length [41]. Reference [24] also showed a large effect size (Cohen's d = -1.06) in a short-term intervention (2 times/week, 35 minutes/session) over eight weeks [24]. This highlights the benefit of Pilates exercise shown with minimal durations, distinguishing it from general prenatal exercises. This could be attributed to Pilates exercise's unique approach of neuromuscular coordination through controlled movements with diaphragmatic breathing. A previous study showed that specific breathing patterns (e.g. deep breathing) regulate intra-abdominal pressure by activating core muscles, which could possibly provide rationale for Pilates exercise's potential benefit in factors relevant to labor progression [42,43]. Furthermore, controlled movements and dynamic stretching of Pilates exercise are in line with principles shown to improve fascial mobility, which may promote elastic recoil, potentially making uterine contractions more efficient during labor [44]. However, more physical activity research is needed to accurately evaluate how Pilates exercise affects labor progression and efficacy from a biomechanical perspective. In addition, the flexibility and adaptability shown with short duration leading to benefits demonstrate its possibility as a practical exercise for pregnant women who may have physical or time constraints.

5. Limitations

Several limitations were included in this review work. First of all, the substantial heterogeneity observed across seven outcomes could not be addressed through sensitivity or subgroup analyses due to insufficient comparable studies, preventing exploration of potential moderators influencing Pilates' effectiveness. The limited duplicates in outcome measures and varying assessment methods across studies underscores the urgent need for standardized outcome sets and intervention protocols to enhance research comparability and replication. Furthermore, while focusing on healthy adult women enabled more reliable comparisons across studies, this population restriction may limit the generalizability of results for more diverse women groups. Finally, the significant effects of Pilates exercise on labor pain and time should be cautiously interpreted due to potential confounding features such as the use of epidural anesthesia or infusion of oxytocin.

6. Conclusion

This umbrella review with meta-analysis discussed both the promise and limitations of Pilates exercise interventions for women's diverse health outcomes. Meta-analyses demonstrated significant improvements in physical function domains, particularly flexibility and cardiorespiratory fitness, and notable benefits for labor-related outcomes. However, the review identified critical gaps in current Pilates exercise intervention research, including inconsistent methodological quality, lack of theoretical frameworks, and substantial heterogeneity in intervention protocols. To advance the field, future research should prioritize: (1) development of standardized, evidence-based Pilates exercise protocols with clear implementation guidelines, (2) incorporation of theoretical frameworks to strengthen intervention design and explain underlying mechanisms, and (3) rigorous methodological approaches with standardized outcome measures. These improvements would enhance the quality of evidence supporting Pilates as an effective exercise modality for women's health promotion and provide clearer guidance for clinical practice.

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