Accepted Manuscript

Title: Pilates in noncommunicable diseases: a systematic review of its effects

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PII: S0965-2299(18)30259-0
DOI: https://doi.org/10.1016/j.ctim.2018.05.018
Reference: YCTIM 1859

To appear in: *Complementary Therapies in Medicine*

Received date: 23-3-2018
Revised date: 31-5-2018
Accepted date: 31-5-2018

Please cite this article as: Miranda S, Marques A, Pilates in noncommunicable diseases: a systematic review of its effects, *Complementary Therapies in Medicine* (2018), https://doi.org/10.1016/j.ctim.2018.05.018

Pilates in noncommunicable diseases: a systematic review of its effects

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Word count: 3500

Highlights of the systematic review:

- Due to the strong evidence presented, Pilates should be considered for improving exercise tolerance in people with NCDs;
- Practice of Pilates as a complementary therapy for people with NCDs might produce additional benefits on symptoms, muscle strength and health-related quality of life.
- Additional studies with robust methodologies are needed to enhance our knowledge on Pilates effectiveness in several health domains.

Abstract

Objectives: Chronic cardiovascular diseases, cancer, chronic respiratory diseases and diabetes are the four major groups of non-communicable diseases (NCDs) and the main cause of mortality worldwide. Pilates has been described as an effective intervention to promote healthy behaviors and physical activity in people with chronic diseases. However, the evidence of its effects in NCDs have not been systematized. We investigated the effects of Pilates in the four major groups of NCDs. **Design:** A systematic review was performed. Searches were conducted on Cochrane Library, EBSCO, PubMed, Science Direct, Scopus and Web of Science databases. Studies were rated with the quality assessment tool for quantitative studies. As a meta-analysis was not possible to conduct, a best-evidence synthesis was used.

Results: Twelve studies, mostly of moderate quality, were included with 491 participants (78.6% females; age range 13.7-70 years old) with breast cancer (n=3), diabetes (n=3), chronic stroke (2 years post stroke) (n=2), chronic obstructive pulmonary disease (n=1), cystic fibrosis (n=1), heart failure (n=1) and arterial hypertension (n=1). The best-evidence synthesis revealed strong evidence for improving exercise tolerance; moderate evidence for improving symptoms, muscle strength and health-related quality of life and limited or conflicting evidence on vital signs, metabolic parameters, body composition, respiratory function, functional status, balance, flexibility and social support.

Conclusions: Pilates should be considered for patients with NCDs, as it improves exercise tolerance. Future studies with robust methodologies are still needed to clarify its effectiveness on outcomes with moderate, limited or conflicting evidence and to establish the most suitable intervention protocol.

Keywords: Pilates; exercise training; complementary medicine; noncommunicable diseases

1. Introduction

Noncommunicable diseases (NCDs) are the main cause of mortality worldwide and derive in substantial socioeconomic burden, entailing thousands of years lived with disability[1-3]. Chronic cardiovascular diseases, cancer, chronic respiratory diseases and diabetes are the four major groups of NCDs, accounting for 82% of all NCDs' deaths[4-7]. These diseases are associated with modifiable risk factors, such as cigarette smoking, hypertension, dyslipidaemia, obesity, physical inactivity and poor nutrition, and could be prevented or controlled by adopting a healthy lifestyle[8-11]. Pilates has been described as an effective intervention to improve physical activity levels and healthy behaviours, emerging as a novel intervention for the treatment of chronic diseases[12].

Pilates was created by Joseph Pilates in the 1920s and its philosophy relies on the tenet "balance of body and mind"[13]. It is a versatile exercise that covers six principles: centring, concentration, control, precision, flow and breathing[14]. Pilates has gained popularity through the years for its benefits on muscle endurance, flexibility and dynamic balance in healthy people[15], and its ability to improve pain, function and kinesiophobia in people with disability (e.g., patients with chronic low back pain)[16]. Moreover, recent studies suggest that this intervention has potential to maximize the physical and mental health of people living with NCDs[17-20]. However, the evidence of Pilates in these conditions has never been systematized. Therefore, this review aimed to investigate the effects of Pilates in the four major groups of NCDs – chronic cardiovascular diseases, cancer, chronic respiratory diseases and diabetes.

2. Material and Methods

2.1 Study Design

This systematic review was followed the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines[21]. The protocol was registered in the international prospective register of systematic reviews (PROSPERO) (ID: CRD42016050050).

2.2 Search strategy

Preliminary searches were first conducted in the Cochrane Library and PROSPERO to exclude the existence of a similar review. A comprehensive systematic search was then conducted in the following electronic databases: Cochrane Library (1999-2017), EBSCO (1974-2017), PubMed (1996-2017), Science Direct (1997-2017), Scopus (1960-2017) and Web of Science

(1900-2017) on the 15th of November 2016. Additional searches were performed in weekly automatic updates retrieved from the databases until November 2017. The detailed search can be found on appendix 1. The references of the included studies and key reviews were hand searched for potentially eligible studies.

2.3 Eligibility Criteria

Studies were considered eligible if (1) included participants with the most common NCDs, i.e., chronic respiratory diseases, chronic cardiovascular diseases, cancer or diabetes; (2) described any Pilates intervention and (3) reported at least one clinical or patient-reported outcome. Searches were restricted to studies published in English, Spanish, French and Portuguese.

Studies were excluded if they referred only proxy versions of the outcome measures. Guidelines, systematic reviews, qualitative studies, news, research protocols, theses, dissertations, abstracts, letters to the editor and unpublished work were also excluded, although their references were searched for relevant articles.

2.4 Selection of studies

One author screened each article for type of publication and relevance for the scope of the review, according to their title, abstract and keywords. If this information suggested that the study could fit the inclusion criteria of the systematic review, the full article was further assessed. The full-text of each potentially relevant study was screened for its content and in cases of uncertainty, the decision to include/exclude the study was debated between two reviewers until reaching consensus.

2. 5 Data extraction

One reviewer extracted the data to two pre-developed and structured tables (i.e., clinical and patient-reported outcomes). Data extracted were: author's name, year and country of publication, study design, participants' characteristics (i.e., health condition, percentage of males, age) type of intervention(s) or comparator(s), measures and outcomes used and quantitative findings. Two reviewers checked the extracted data for accuracy and completeness. Reviewers resolved disagreements by consensus. Authors of the included studies were contacted for missing data.

2.6 Quality Assessment

The methodological quality of the included studies was assessed by two independent reviewers using the quality assessment tool for quantitative studies[22]. This tool, developed by the effective public health practice project (EPHPP), is composed of eight sections: 1) selection bias; 2) study design; 3) confounders; 4) blinding; 5) data collection methods; 6) withdrawals and dropouts; 7) intervention integrity and 8) analysis. The overall methodology of studies is rated as strong (no weak ratings in all sections), moderate (one weak rating) or weak (two or more weak ratings)[22]. Agreement was reached by consensus between the two independent reviewers.

2.7 Data analysis

Inter-rater agreement of the quality assessment was explored using Cohen's kappa. The value of Cohen's kappa was interpreted as i) <0: poor agreement; ii) 0.00-0.20: slight agreement; iii) 0.21-0.40: fair agreement; iv) 0.41-0.60: moderate agreement; 0.61-0.80: substantial agreement; vi) 0.81-1.00: almost perfect agreement[23].

Due to the diversity of the outcome measures used in the selected studies, a meta-analysis was not possible to conduct. Instead, a summary of the results was performed using a best-evidence synthesis[24] (Table 4). This analysis considered the number, methodological quality and consistency of outcomes of the studies, using 5 levels of evidence: (1) strong evidence, provided by consistent findings among multiple (≥2) high quality randomized controlled trials (RCTs); (2) moderate evidence, provided by consistent findings among multiple low quality RCTs and/or non-randomized controlled clinical trials (CCTs) and/or one high quality RCT; (3) limited evidence, provided by only one low quality RCT and/or CCT; (4) conflicting evidence, provided by inconsistent findings among multiple trials (RCTs and/or CCTs) and (5) no evidence, when no RCTs or CCTs are found[25].

Effect sizes (ES) for each outcome measure were calculated using comprehensive meta-analysis (CMA) software (Biostat, Englewood, New Jersey)[26] and interpreted as small ($0.2 \le d < 0.5$), medium ($0.5 \le d < 0.8$) and large ($d \ge 0.8$)[27].

3. Results

3.1 Study selection

The databases search identified 676 studies and 11 additional studies were found through key reviews. After duplicates removal, 482 studies were screened for potential content. During the title, abstract and keyword screening, 423 articles were excluded. The full-text of 59 potentially relevant articles was assessed and 47 articles were excluded due to the following reasons: i) full-text was not available[28]; ii) population included diseases other than chronic cardiovascular, chronic respiratory, cancer and diabetes[29-36]; iii) type of intervention was not Pilates[37-58]; iv) type of study was a qualitative study, news, research protocol or letters to the editor[7, 10, 59-64,65] and v) study was not written in English, Spanish, French or Portuguese languages[66-69]. Twelve studies were included. A detailed flow diagram of the review process is presented in figure 1.

3.2 Quality Assessment

From the articles included in this review, eight scored moderate[70-77], three scored strong[78-80] and one scored weak[81] quality (Table 1). The agreement between the two reviewers was almost perfect (k=0.84; 95%CI [0.38–1]).

3.3 Study characteristics

Studies varied in their design. Nine were RCTs[70-72, 74, 77-81] and three were pre-post design[73, 75, 76]. A total of 491 participants (78.6% females; age range 13.7-70 years old) were recruited among studies conducted in breast cancer[70, 71, 79], diabetes[74, 75, 81], chronic stroke (2 years post stroke)[77, 80], chronic obstructive pulmonary disease (COPD)[72], cystic fibrosis[73], heart failure[78] and arterial hypertension[76].

Generally, the interventions ranged from 8 to 16 weeks, with a frequency of 1 to 3 times per week and each session lasted between 40 and 90 minutes. Five studies had additional exercises (i.e., walking and swimming) included in their intervention[70, 77-80] and one study delivered an educational session[70]. Some of the studies reporting usual care as a comparator, did not provide a clear description of the possible undergoing treatments[76, 81]. Study characteristics are presented in Table 2 and Table 3.

3. 4 Synthesis of the results

3.4.1 Symptoms

Physical symptoms were assessed using the visual analogue scale (VAS) for pain[71, 74, 79] and fatigue[74], brief fatigue inventory for fatigue[70], social appearance anxiety scale (SAA) for anxiety[79], the hospital anxiety and depression scale (HADS)[74] for anxiety and depression, Beck's depression inventory (BDI) for depression[70], and the 36-item short form survey (SF-36)[74] and the 28-item general health questionnaire (GHQ-28) for physical symptoms globally[75]. Significant improvements were reported for pain (p=0.001-0.01, ES=-12.70--0.27)[74, 75], fatigue (p=0.001, ES=-0.25)[74], anxiety (p=0.04-0.023, ES=0.0-1.52) and depression symptoms (p=0.019-0.01, ES= 0.0--1.38)[74, 75] and general mental health (p=0.001, ES=0.0)[74] in patients with type 2 diabetes. Significant improvements were also observed for pain (p=0.004-0.01, ES=0.0-0.4)[71, 79] and anxiety (p<0.01 ES=-0.4)[79] and depression (p=0.01, ES=-0.09)[70] in patients with breast cancer however, no differences between groups were reported. In the best-evidence synthesis analysis, moderate evidence was found (Table 4).

3.4.2 Vital signs

A variety of vital signs using different equipment have been assessed in Pilates interventions, namely peripheral oxygen saturation (SpO_2) with oximetry[72]; heart rate at rest with electrocardiogram during cardiopulmonary exercise testing (CPET)[78, 80] or an oscillometric device[76]; respiratory rate with plethysmography[72] and blood pressure with the auscultation method during CPET [14] and an oscillometric device[76, 78].

Peripheral oxygen saturation increased significantly (p<0.05, ES=0.16) with Pilates breathing when compared to natural breathing, although diaphragmatic breathing was found to be even of more benefit[72]. Respiratory rate increased significantly (p<0.05, ES=0.12) with Pilates breathing in patients with COPD when compared to diaphragmatic breathing. Results also improved significantly for diastolic blood pressure (DBP) of patients with heart failure (p=0.02, ES=-0.24)[78] and for both DBP ($p<0.05$, ES= -0.35) and systolic blood pressure (SBP) ($p<0.05$, ES=-0.59) in patients with arterial hypertension[76]; though no differences were found in patients with COPD when compared to controls[72]. Conflicting results were however found for heart rate, as no differences were reported in patients with heart failure ($p>0.05$, ES=-0.05)[78] and arterial hypertension ($p>0.05$, ES=-0.26)[76] while significant improvements (i.e., reduced heart rate) were observed in patients with chronic stroke ($p<0.05$, ES=-0.49)[80]. The overall analysis of best-evidence synthesis on vital signs showed conflicting evidence (Table 4).

3.4.3 Metabolic parameters

Glycated hemoglobin (Hba1c), daily insulin doses (DID), high density lipoprotein (HDL), high density lipoprotein (LDL), total cholesterol (T col) and triglyceride (TG) were assessed through metabolic analysis of patients with type 1 diabetes[81]. No significant improvements were reported for the experimental group (EG) ($p>0.05$) whereas in the control group (CG) a significant improvement was reported in HDL ($p=0.046$, ES=-0.14)[81]. As only one study assessed this outcome, limited evidence on the best-evidence synthesis analysis was found (Table 4).

3.4.4 Body composition

Body mass (BM), body mass index (BMI), waist and hip circumferences were assessed using calculations and an anthropometric tape in patients with arterial hypertension[76]. Significant improvements were only found in waist ($p<0.05$, ES=-0.27) and hip circumferences ($p<0.05$, ES=-0.31)[76]. Similarly, to metabolic parameters, the evidence presented in the best-evidence synthesis was also limited (Table 4).

3.4.5 Muscle strength

Upper[71, 76, 79], lower limb[81] and respiratory[73] muscle strength was assessed. The lower limb was assessed with the vertical jump test and the modified Wingate test for anaerobic capacity[81], the upper limb with the hand-held dynamometer[71] and the handgrip dynamometer[71, 76, 79] and respiratory muscle strength with a pressure manometer in patients with breast cancer[71, 79], arterial hypertension[76], type 1 diabetes[81] and cystic fibrosis[73].

Shoulder strength was found to improve significantly during flexion (p=0.019, ES=0.14), abduction (p=0.001, ES=0.10), internal (p=0.015, ES=0.10) and external rotation, (p=0.017, ES=0.10) in patients with breast cancer without differences between groups[71]. Significant improvements in handgrip strength (p=0.01-0.49, ES=0.14-0.63) in both patients with breast cancer[71, 79] and arterial hypertension were also reported[76].

In patients with type 1 diabetes, significant improvements in lower limb strength were reported, particularly in jump height (p=0.003, ES=0.15), mean power (p<0.001, ES=0.10) and peak power (p=0.02, ES=0.20)[81].

Regarding respiratory muscle strength, significant improvements in maximum inspiratory pressure (MIP) in both male (p=0.017, ES=0.11) and female (p=0.005, ES=1.19) patients were reported, while maximum expiratory pressure (MEP) only improved in female patients (p=0.007, ES=0.87)[73]. Moderate evidence in the best-evidence synthesis analysis was found (Table 4).

3.4.6 Respiratory function

Respiratory pattern was assessed using inductive plethysmography in patients with COPD and healthy people[72] and lung volumes were assessed using spirometry in patients with cystic fibrosis[73].

Significant differences in favor of diaphragmatic breathing, rather than Pilates in inspiratory ($p<0.05$, ES=0.87), expiratory volumes ($p<0.05$, ES=1.20) and phase angle ($p<0.05$, ES=0.86) were reported[72]. No significant changes were found in forced expiratory volume in one second (FEV_1) or forced vital capacity (FVC), both in male (p=0.598, ES=0.10; p=0.555, ES=0.09) and female patients (p=0.463, ES=0.08; p=0.964, ES=0.05)[73]. The best-evidence analysis presented limited evidence (Table 4).

3.4.7 Functional status

This outcome was assessed using the constant-Murley score[71] and the disabilities of the arm, shoulder, and hand scale (DASH)[79] in patients with breast cancer, and the timed up and go test (TUG) in chronic stroke patients[80]. Significant improvements were reported in patients with breast cancer ($p<0.01$, ES=0.21-0.24)[71, 79] and in chronic stroke patients ($p<0.05$, ES=-0.82)[80], though in one of the studies on patients with breast cancer no differences between groups were found[79]. The best-evidence synthesis presented conflicting evidence for functional status (Table 4).

3.4.8 Exercise tolerance

Exercise tolerance was assessed using the 6-minute walk test in patients with breast cancer[70] and CPET in patients with heart failure and chronic stroke[78, 80].

Significant improvements were reported in 6-minute walking distance (6MWD) ($p<0.01$, ES=1.28)[70], peak oxygen consumption (peak VO_2) (p=0.02, ES=0.46-0.53)[78,80], pulse O_2 (p=0.003, ES=0.35) and time achieved during CPET ($p<0.001$, ES=0.55)[78]. No significant changes regarding respiratory exchange ratio (RER) and minute ventilation (VE/VCO_2) were reported (p>0.05)[78]. Strong evidence was found in the best-evidence synthesis analysis (Table 4).

3.4.9 Balance

This outcome was assessed using an instrumented treadmill with force plates in patients with chronic stroke[77]. Significant improvements were reported for static balance, specifically in medial-lateral (p<0.05, ES=-1.36) and anterior-posterior (p<0.05, ES=-0.67) center of pressure (COP) and medial-lateral (p<0.05, ES=-0.41) and anterior-posterior (p<0.001, ES=-0.42) velocity. Dynamic balance of both paretic and non-paretic sides also showed significant improvements in medial-lateral (p<0.05, ES=-1.28 to -1.71) and anterior-posterior (p<0.001, ES=-1.27--1.71) COP and medial-lateral (p<0.001, ES=-0.3 to -0.43) and anterior-posterior (p<0.01, ES=-0.46 to -0.53) velocities[77]. The analysis of best-evidence synthesis presented limited evidence as only one study assessed this outcome (Table 4).

3.4.10 Flexibility

Flexibility was assessed with the sit-and-reach test in patients with breast cancer and diabetes[70, 81], the bank of wells test in patients with arterial hypertension[76] and range of motion (ROM) of the shoulder using a goniometer in patients with breast cancer[71, 79].

Significant improvements were reported in patients with diabetes (p<0.001, ES=0.94) [81] and arterial hypertension[76] (p<0.05, ES=0.52), though in patients with breast cancer, one study found no significant changes[70] while others found a significant improvement in shoulder flexion (p=0.001-0.01; ES=0.16-0.51) and abduction (p=0.002-0.01; ES=0.11-0.38)[71, 79]. Regarding external rotation of the shoulder, conflicting results were found, as one of the studies found a significant improvement (p=0.007, ES=0.21)[71] while the other reported no significant changes (p=0.15)[79]. In the analysis of best-evidence synthesis, conflicting evidence was found (Table 4).

3.4.11 Quality of life

Health-related quality of life (HRQoL) was assessed using the european organization for the research and treatment of cancer quality of life questionnaire (EORTC QLQ-C30)[70], the european organization for the research and treatment of cancer quality of life questionnaire breast cancer module 23 (EORTC QLQ-BR23) in patients with breast cancer[70, 79] and 36-item short form survey (SF-36) in patients with diabetes[74].

Significant improvements were reported for HRQoL (p=0.03-0.04, ES=0.01-0.53) in patients with breast cancer (with no differences between groups) (p=0.94)[70, 79] and for mental health HRQoL (p=0.001, ES=0.0) in patients with diabetes[74]. The best-evidence synthesis presented moderate evidence for the effects of Pilates on HRQoL (Table 4).

3.4.12 Social support

Only one study assessed social support using GHQ-28 in patients with type 2 diabetes and a significant improvement was found (p=0.001, ES=-1.73)[75].

The best-evidence synthesis presented limited evidence for social support (Table 4).

4. Discussion

To the authors' best knowledge this was the first study to systematically review Pilates effects across multiple NCDs.

The best-evidence synthesis showed strong evidence for exercise tolerance; moderate evidence for symptoms, muscle strength and HRQoL; limited evidence for metabolic parameters, body composition, respiratory function, balance and social support and conflicting evidence for vital signs, functional status and flexibility; when using Pilates in NCDs. Overall Pilates had larger effects on diabetes, followed by chronic respiratory and cardiovascular diseases and cancer. High levels of comorbidities have been reported in patients with chronic respiratory and cardiovascular diseases and cancer which will affect their functional capacity, health status and quality of life[82-85]. Therefore, more comprehensive Pilates interventions, with longer duration, intensity and adjusted exercises (such as aerobic training) might be required for people with these NCD. Indeed, the most appropriate Pilates protocol for each NCD is still to ascertain. Based on the findings of this systematic review, longer (>8 weeks) interventions with additional components (educational sessions or home exercises), at least three times a week, seem to be more effective.

Although exercise tolerance was assessed with different outcome measures, its improvement with Pilates was unequivocal. As improving exercise tolerance is fundamental to manage these lifestyle-related diseases[86], Pilates seems to be an important intervention to be encouraged, as it is effective and is perceived as a soft and enjoyable approach for patients[87, 88]. Nevertheless, the effects of Pilates on exercise tolerance were limited to patients with breast cancer and cardiovascular diseases and therefore, its effects on other conditions are still unknown.

The moderate evidence found for symptoms, muscle strength and HRQoL might be due to the heterogeneity of the outcome measures used, the wide age range of participants, the different approaches to Pilates, and/or poor methodologies used by the studies. Nevertheless, positive effects of Pilates on symptoms, muscle strength and HRQoL were reported in all studies assessing these outcomes. Given the negative multi-systemic effects (e.g., skeletal muscle impairment, mood disturbance, hormonal imbalance and immunological incompetence) inherent to NCDs[89-91] and the positive effects of Pilates found in all studies, research with more robust methodologies is urgently needed.

The limited evidence found on five of the twelve outcomes (metabolic parameters, body composition, respiratory function, balance and social support) was due to the scarce number of studies, hampering the assessment of Pilates overall effectiveness. However, few studies suggested that Pilates was effective in improving body composition, respiratory function, balance and social support. This is of special importance, since these parameters, are modifiable factors that can contribute to falls, considered a major public health issue worldwide[92]. Moreover, social support has been found to be associated with better health outcomes, being a protective factor for mental and physical health[93]. Although previous studies have shown improvements on these outcomes with Pilates, they were conducted in healthy adults and elderly women[94-96], with much less known about them in people with NCDs. Given the social, economic and health burden of NCDs worldwide[1], further research using Pilates on these outcomes seem a priority.

Whilst there was conflicting evidence of the effects of Pilates on vital signs, for some parameters (i.e., SpO_2, DBP and respiratory rate), global positive effects were found in all studies. Similarly, most studies reported a positive effect on functional status and flexibility, although there were still few studies reporting no effects with the intervention. Since poor functional status is a predictor of mortality, a risk factor for developing emotional disorders and hospital readmissions[97-99], and flexibility might be a predictor of arterial stiffening and musculotendinous disorders[100], the need for additional studies is imperative.

Finally, physical activity and self-efficacy are also fundamental aspects to consider when treating people with NCDs, as they are strong predictors of HRQoL in these patients[101]. Although Pilates is an effective tool for enhancing physical activity in other populations[12], this has not been explored in people with NCDs. Moreover, fundamental everyday behaviours such as daily-living activities are not being assessed in Pilates interventions. Therefore, new studies are needed to explore its effects on these outcomes in patients with NCDs.

This systematic review has some limitations. Primarily, the different study designs and measures used in both patient-reported and clinical outcomes hampered the results' synthesis and the conduction of meta-analysis. Nevertheless, the best-evidence synthesis provided a thorough and unbiased means of synthesizing the research developed, and provided clear conclusions. Another limitation was the lack of a clear description of usual care on control groups, which might have led to a poor estimation of the treatment effect inhibiting its comparison with other interventions. Lastly, samples were mainly composed of female participants, being inappropriate to generalize the results to both genders. Thus, future studies should integrate male patients to determine if similar results are found in the whole spectrum of these populations.

5. Conclusion

Findings from this show that Pilates improves exercise tolerance and could play an important role on symptoms, muscle strength and HRQoL of people with NCDs.

Due to limited or conflicting evidence on other outcomes, future studies with homogeneous outcome measures across the four major NCDs are needed.

Although the best Pilates protocol for each NCD is yet to ascertain, more comprehensive interventions, superior to 8 weeks, seem to be more effective. Though additional research is still needed, Pilates should be taken into account as an adjunct intervention for the treatment of these patients, as it is an appealing and effective form of exercise.

Declarations of interest: none.

Funding: this work was not funded.

Conflict of Interest: none

Acknowledgements

The authors thank the members of Lab 3R – Respiratory Research and Rehabilitation Laboratory for their helpful comments in the preparation of this article.

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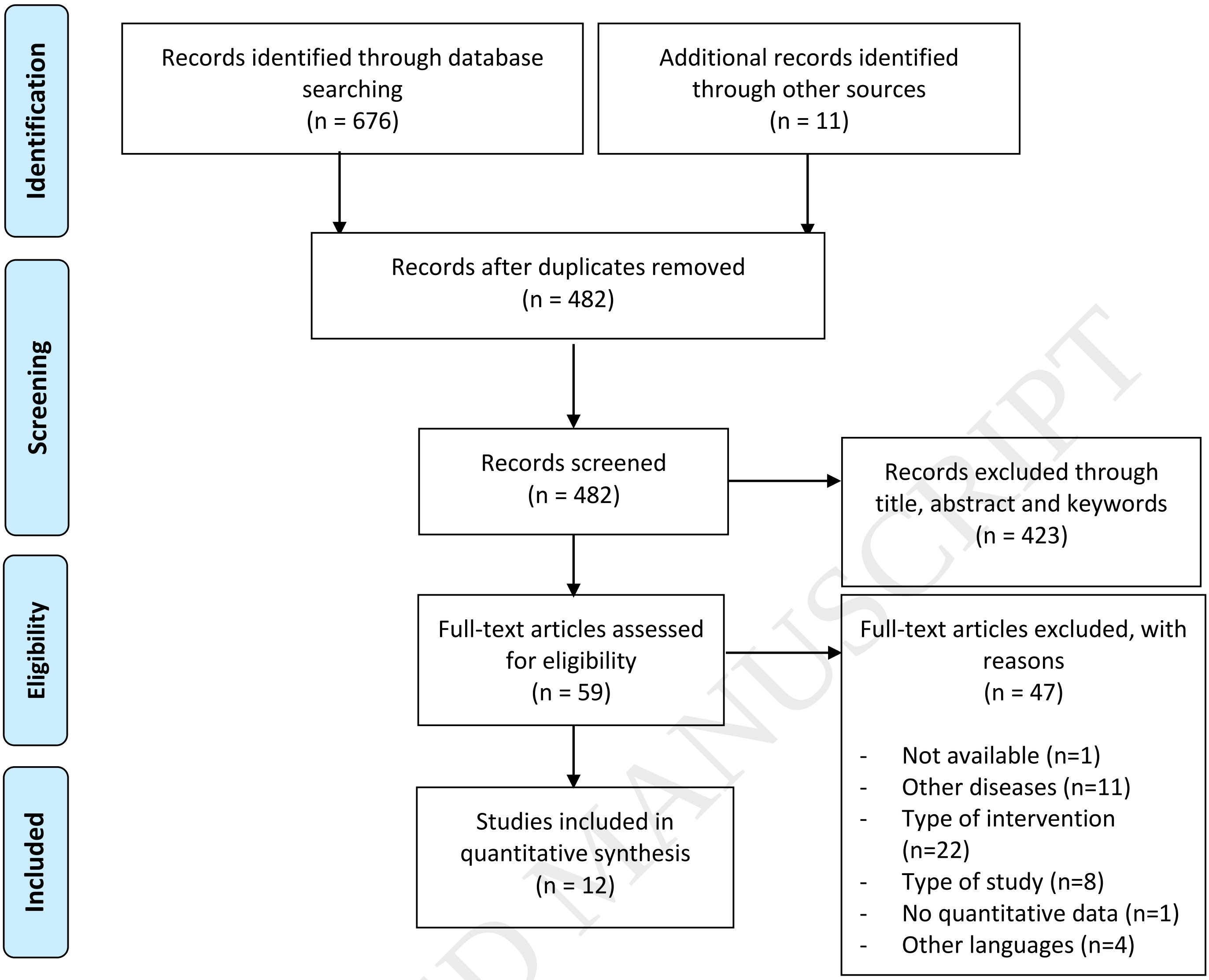

Figure 1 - Flow diagram for study selection according to the preferred reporting items for systematic review and meta-analysis (PRISMA) guidelines

Table 1 - Quality assessment based on the quality assessment tool for quantitative studies' criteria

Author (year)	**Selection bias**	**Study design**	**Confounders**	**Blinding**	**Data collection method**	**Withdrawals and dropouts**	**Global rating**
Tunar et al. (2012)	2	1	3	2	3	1	3
Eygor et al. (2010)	2	1	1	2	3	2	2
Zengin et al. (2016)	2	1	3	2	1	1	2
Sener et al. (2017)	2	1	1	2	1	1	1
Cancelliero-Gaiad et al. (2014)	3	1	1	2	1	1	2
Franco et al. (2014)	2	2	3	2	1	2	2
Guimarães et al. (2012)	2	1	1	2	1	1	1
Martins-Meneses et al. (2014)	3	1	1	2	2	2	2
Sung et al. (2016)	2	1	1	2	3	1	2
Lim et al. (2017)	2	1	1	2	1	1	1
Torabian et al. (2013)	2	1	1	2	1	3	2
Yucel and Uysal (2015)	2	1	3	2	1	2	2

1: strong quality; 2: moderate quality; 3: weak quality.

Table 2 - Effects of Pilates in noncommunicable diseases- clinical outcomes (non-patient reported) and outcome measures

Author (Year)/Country	Study Design	Participants	Intervention	Outcomes	Outcome Measures	Key Findings
Tunar et al (2012)/Turkey	RCT	Type 1 Diabetes: n=31 Intervention: n=17; 35%male; 14.2±2.2yrs Control: n=14; 64%male; 14.3 ± 1.8yrs	Duration: 12 weeks Frequency: 40 min. supervised 3 days/wk Components EG: • warm-up and cool down - 5 min. • Pilates exercises 8 exercises, 3 sets of 6 to 10 repetitions with 30 s active rest for each exercise CG: Usual Care	Flexibility	Sit-and-reach (cm)	EG: Pre 0.4±5.2; Post 8.4±5.2, p<0.001 CG: Pre 1.5±6.3; Post 2.9±6.5, p>0.05 ES=0.94
				Lower limb strength	Vertical jump test Height (cm)	EG: Pre 35.7±10.2; Post 39.2±10, p=0.003 CG: Pre 42.1±8; Post 43.9±7.4, p>0.05 ES=0.15
					Modified Wingate test Mean power (W)	EG: Pre 362.2±177.8; Post 386.5±180.7, p<0.001 CG: Pre 401±104; Post 407.5±114.1, p>0.05 ES=0.10
					Peak power (W)	EG: Pre 491.2±236.5; Post 509.6±226.8, p=0.02 CG: Pre 549.2±161.4; Post 519.3±133.2, p>0.05 ES=0.20
				Metabolic parameters HbA1c (%)	Metabolic analysis	EG: Pre 8.9±1.6; Post 8.8±1.5, p>0.05 CG: Pre 9.2±2.1; Post 8.7±1.8, p>0.05 ES=-0.19
				DID (u/kg)		EG: Pre 1.1±0.3; Post 1±0.2, p>0.05 CG: Pre 1±0.2; Post 1±0.2, p>0.05 ES=-0.35

			HDL (mg/dl)		EG: Pre 53.9±11.5; Post 56.9±9.6, p>0.05 CG: Pre 58±12.8; Post 64±17.1, p=0.046 ES=-0.14
			LDL (mg/dl)		EG: Pre 87.4±18.1; Post 85.3±14.6, p>0.05 CG: Pre 94.8±25.9; Post 99.1±32.8, p>0.05 ES=-0.22
			T Col (mgl/dl)		EG: Pre 167.4±23.4; Post 167.5±25.8, p>0.05 CG: Pre 195.6±62.3; Post 196.1±62.1, p>0.05 ES=-0.01
			TG (mg/dl)		EG: Pre 85.9±40.2; Post 89.9±46.8, p>0.05 CG: Pre 104.1±80.2; Post 95.1±57.5, p>0.05 ES=-0.19
Eygor et al (2010)/Turkey	RCT	Breast Cancer: n=41 Intervention: n=27; 0%male; 48.5±7.6yrs Control: n=15; 0%male; 49.7±8.7yrs	Duration: 8 weeks Frequency: 60 min. supervised and 20-30 min. unsupervised 3 days/wk, Components EG: · warm-up and cool down breathing and stretching exercises · Pilates exercises 2 sets of 10 repetitions · education session - 30 min.	Exercise tolerance	6MWD (m)	EG: Pre 496.3±47.1; Post 522.6±42.0, p=0.00 CG: Pre 506.7±44.5; Post 466.0±32.9, p=0.02 EG vs CG p<0.01 ES=1.28

			• unsupervised exercises from a booklet - once a day • unsupervised walk – 20 to 30 min. 3days/wk • Components CG: • education session - 30 min. • unsupervised exercises from a booklet - once a day • unsupervised walk – 20 to 30 min. 3days/wk	Flexibility	Modified sit-and-reach test (inches)	EG: Pre 8.0±10.2; Post 8.9±7.3, p=0.25 CG: Pre 5.0±4.4; Post 5.0±4.8, p=0.86 EG vs CG p=0.21 ES=0.09
Zengin et al (2016)/Turkey	RCT	Breast Cancer: n=56	Duration: 8 weeks Frequency: 45 min. supervised 3 days/wk	Flexibility	Goniometer (º)	
		PG: n=18; 0%male; 46.2 ± 11.2yrs	Components PG: • Teaching of key elements of Pilates • Pilates-based mat exercises • Pilates-based theraband exercises	Shoulder flexion		PEG: Pre 150.8±12.3; Post 160.5±12.9, p=0.001 CEG: Pre 149.2±9.6; Post 166.2±7.8, p<0.001 HEG: Pre 147.3±22.6; Post 157.9±13.5, p=0.019 PEG vs CEG vs HEG p=0.012 ES=0.16
		CEG: n=18; 0%male; 51.9 ± 8.0yrs	Components CEG: • Stretching • ROM • Shoulder strengthening exercises • breathing exercises	Shoulder abduction		PEG: Pre 133.4±23.7; Post 153.1±20.8, p=0.002 CEG: Pre 128.7±20.5; Post 155.3±13.7, p<0.001 HEG: Pre 130.2±32.3; Post 145.9±24.5, p=0.002 PEG vs CEG vs HEG p>0.05 ES=0.11
		HEG: n=19; 0%male; 51.5 ± 13.8yrs	Duration: 8 weeks Frequency: 3 days/wk unsupervised Components HEG:	Shoulder internal rotation		PEG: Pre 71.7±8.2; Post 75.0±8.3, p=0.029 CEG: Pre 67.8±9.2; Post 79.1±7.0, p<0.001 HEG: Pre 68.4±12.5; Post 70.5±11.0, p=0.280 PEG vs CEG vs HEG p=0.00

	Individual exercise program taught by a physiotherapist. Stretching ROM Shoulder strengthening exercises breathing exercises			ES=0.17
		Shoulder external rotation		PEG: Pre 74.5±10.1; Post 80.8±10.0, p=0.007 CEG: Pre 61.8±12.2; Post 75.9±9.5, p<0.001 HEG: Pre 67.8±17.7; Post 74.6±13.3, p=0.055 PEG vs CEG vs HEG p=0.002 ES=0.21
		Shoulder strength	Hand-held dynamometer (kgf)	
		Flexion		PEG: Pre 4.9±1.2; Post 6.2±1.5, p=0.001 CEG: Pre 5.1±1.4; Post 6.2±1.4, p=0.016 HEG: Pre 4.2±1.1; Post 4.9±1.6, p=0.041 PEG vs CEG vs HEG p=0.019 ES=0.14
		Abduction		PEG: Pre 4.5±1.3; Post 5.7±1.6, p=0.001 CEG: Pre 4.5±1.1; Post 5.5±1.5, p=0.010 HEG: Pre 3.9±1.1; Post 4.4±1.3, p=0.036 PEG vs CEG vs HEG p > 0.05 ES=0.10
		Internal rotation		PEG: Pre 6.5±1.8; Post 7.6±1.1, p=0.015 CEG: Pre 5.8±2.2 Post 7.0±2.0, p=0.036 HEG: Pre 5.7±1.7; Post 6.0±2.0, p=0.319 PEG vs CEG vs HEG p> 0.05 ES=0.10
		External rotation		PEG: Pre 6.1±1.7; Post 7.2±2.0, p=0.017 CEG: Pre 6.0±1.9; Post 7.1±1.7, p=0.026

						HEG: Pre 5.1±1.7; Post 5.3±1.8, p=0.542
						PEG vs CEG vs HEG p> 0.05
						ES=0.10
				Hand strength	Hand-held dynamometer (kg)	
				Grip		PEG: Pre 21.0±6.8; Post, NR p= 0.034
						CEG: Pre 19.3±5.3; Post, NR p= 0.031
						HEG: Pre 20.1±3.9, Post, NR p=0.027
						PEG vs CEG vs HEG p>0.05
				Lateral		PEG: Pre 3.9±2.2; Post, NR p= 0.012
						CEG: Pre 3.5±1.7; Post, NR p= 0.038
						HEG: Pre 3.6±1.9; Post, NR p=0.692
						PEG vs CEG vs HEG p>0.05
				Palmar		PEG: Pre 2.6±1.7; Post, NR p=0.016
						CEG: Pre 2.5±1.5; Post, NR p=0.022
						HEG: Pre 1.9±1.5; Post, NR p=0.239
						PEG vs CEG vs HEG p>0.05
				Tip		PEG: Pre 1.9±1.4; Post, NR p=0.023
						CEG: Pre 1.2±0.8; Post, NR p=0.074
						HEG: Pre 1.5±1.2; Post, NR p=0.521
						PEG vs CEG vs HEG p>0.05
				Functional status	Constant–Murley score*	PEG: Pre 56.5±10.7; Post 72.2±6.7, p<0.001
						CEG: Pre 54.8±9.6; Post 69.7±11.7, p<0.001
						HEG: Pre 57.2±13.9; Post 60.1±12.0, p=0.157
						PEG vs CEG vs HEG p<0.001
						ES=0.24
Sener et al	RCT	Breast Cancer	Duration: 8 weeks	Handgrip strength	Handgrip dynamometer (kg)	EG: Pre 17.5±6.7; Post 19.8±6.2, p=0.01
(2017)/Turkey		n=60	Frequency: 3 days/wk			CG: Pre 20.7±6.6; Post 21.9±5.4, p=0.08
			Components EG:			EG vs CG p=0.05

		Intervention: n=30; 0%male; 53.2±7.7yrs Control: n=30; 0%male; 54.0±12.6yrs	• Pilates exercises • Home program – every day manual lymphatic drainage training, wall extension, and Wand exercises Components CG: • Core stabilization exercises • Home program – every day Daily living activities with core protection manual lymphatic drainage shoulder exercises skin care			ES=0.14
				Flexibility	Goniometer (º)	
				Shoulder flexion		EG: Pre 165.3±21.5; Post 179.2±2.7, p=0.01 CG: Pre 172.7±14.1; Post 177.5±6.4, p=0.08 EG vs CG p=0.19 ES=0.51
				Shoulder abduction		EG: Pre 155.5±35.7; Post 177.2±7.4, p=0.01 CG: Pre 163.7±25.9; Post 173.5±16.6, p=0.01 EG vs CG p=0.27 ES=0.38
				Shoulder external rotation		EG: Pre 77.2±22.7; Post 88.67±3.5, p=0.05 CG: Pre 81.8±15.0; Post 85.7±10.7, p=0.22 EG vs CG p=0.15 ES=0.39
Cancelliero-Gaiad et al (2014)/Brazil	RCT	COPD: n=15 Healthy: n=15 Intervention: n=15; 53%male; 65.3±7.3yrs Control:	Duration: 7 repetitions Frequency: 1 Intervention for all participants: • breathing exercises – 7 repetitions natural breathing diaphragmatic breathing Pilates breathing	Respiratory pattern	Inductive plethysmography	
				Inspiratory tidal volume (mL)		EG: NB 397.9±125.3, DB 880.5±421.4 (p<0.05); PB 591.4±377.5 (p<0.05) CG: NB 361.9±145.4; DB 1347.8±524.3 (p<0.05); PB 948.6±439.3 (p<0.05) EG vs CG p<0.05 ES NB=0.26; ES DB=0.00; ES PB=0.87
				Expiratory tidal volume (mL)		EG: NB 400.9±128.7; DB 881.7±426.4 (p<0.05); PB 533.5±291.3 (p<0.05) CG: NB 368.3±145.2; DB 1420.5±584.3 (p<0.05); PB 993.0±457.9 (p<0.05) EG vs CG p<0.05

	n=15; 47%male; 62.5±9.4yrs		ES NB=0.24; ES DB=1.05; ES PB=1.20
		Minute ventilation (L/min)	EG: NB 6.0±2.4; DB 9.8±2.5 (p<0.05); PB 8.9±4.3 (p>0.05) CG: NB 5.6±1.8; DB 13.6±5.6 (p<0.05); PB 14.4±4.7 (p<0.05) EG vs CG p>0.05 ES NB=0.19; ES DB=0.88; ES PB=1.22
		Respiratory rate (cpm)	EG: NB 16.7±3.8; DB 11.0±3.5 (p<0.05); PB 16.9±7.4 (p<0.05) CG: NB 16.4±3.7; DB 11.8±4.8 (p<0.05); PB 16.2±3.4 (p<0.05) EG vs CG p>0.05 ES NB=0.08; ES DB=0.19; ES PB=0.12
		Inspiratory time (s)	EG: NB 1.3±0.3; DB 1.9±0.4 (p<0.05); PB 1.4±0.3 (p<0.05) CG: NB 1.4±0.4; DB 2.9±0.9 (p<0.05); PB 1.8±0.4 (p<0.05) EG vs CG p<0.05 ES NB=0.28; ES DB=1.44; ES PB=1.13
		Expiratory time (s)	EG: NB 2.9±1.3; DB 4.5±2.0 (p<0.05); PB 2.7±0.9 (p<0.05) CG: NB 2.3±0.5; DB 5.2±1.8 (p<0.05); PB 2.5±0.6 (p<0.05) EG vs CG p>0.05 ES NB=0.61; ES DB=0.37; ES PB=0.26

	Total breath time (s)	EG: NB 4.2±1.5; DB 6.4±2.1 (p<0.05); PB 4.1±1.1 (p<0.05) CG: NB 3.7±0.8; DB 8.1±2.5 (p<0.05); PB 4.2±0.9 (p<0.05) EG vs CG p>0.05 ES NB=0.42; ES DB=0.74; ES PB=0.10
	%RCi	EG: NB 54.5±28.1; DB 50.6±48.4; PB 61.1±28.2 (p>0.05) CG: NB 63.3±16.3; DB 66.7±15.5; PB 80.9±18.3 (p<0.05) EG vs CG p>0.05 ES NB=0.38; ES DB=0.45; ES PB=0.83
	Labored breathing index	EG: NB 1.1±0.3; DB 1.2±0.3; PB 1.0±0.0, p>0.05 CG: NB 1.0±0.0; DB 1.1±0.1; PB 1.1±0.1, p>0.05 EG vs CG p>0.05 ES NB=0.47; ES DB=0.45; ES PB=1.41
	Phase relation during inspiration	EG: NB 13.5±12.9; DB 38.8±21.6 (p<0.05); PB 21.4±10.5 (p<0.05), CG: NB 5.7±3.0; DB 29.6±14.6 (p<0.05); PB 25.8±12.3 (p<0.05) EG vs CG p<0.05 in favor of NB ES NB=0.83; ES DB=0.50; ES PB=0.38

		Phase relation during expiration		EG: NB 13.9±8.0; DB 37.1±19.0 ($p<0.05$); PB 21.7±9.8 ($p<0.05$) CG: NB 5.8±2.7; DB 30.7±14.2 ($p<0.05$); PB 28.0±10.1 ($p<0.05$) EG vs CG $p<0.05$ in favor of NB ES NB=1.36; ES DB=0.38; ES PB=0.63
		Phase relation of the entire breath		EG: NB 13.4±8.0; DB 37.2±19.6 ($p<0.05$); PB 22.1±9.5 ($p<0.05$) CG: NB 5.7±2.5; DB 26.8±12.7 ($p<0.05$); PB 26.2±10.4 ($p<0.05$) EG vs CG $p<0.05$ in favor of NB ES NB=1.30; ES DB=0.63; ES PB=0.41
		Phase angle (º)		EG: NB 24.1±22.1; DB 67.0±47.7 ($p<0.05$); PB 30.6±12.3 ($p<0.05$) CG: NB 9.1±4.2; DB 39.1±19.1 ($p<0.05$); PB 21.1±9.5 ($p<0.05$) EG vs CG $p<0.05$ ES NB=0.94; ES DB=0.77; ES PB=0.86
		SpO_2 (%)	Oximetry	EG: NB 95.4±3.4; DB 99.4±1.4 ($p<0.05$); PB 99.3±1.6 ($p<0.05$) CG: NB 97.4±1.6; DB 99.7±0.7 ($p<0.05$); PB 99.5±0.8 ($p<0.05$) EG vs CG $p>0.05$ ES NB=0.75; ES DB=0.27; ES PB=0.16
Cystic Fibrosis:	Duration: 16 weeks	MIP	Respiratory pressures (cmH_2O)	M: Pre 77.9±19.5; Post 101.4±22.7, p=0.017

Franco et al (2014)/Brazil	1 group pre-post design	n=19 37%male; 13.7 ± 7.4yrs	Frequency: 60 min. individual session once a week, Components:			F: Pre 70.8±19.2; Post 92.5±17.3, p=0.005 ES (M)=0.11, ES (F)=1.19
			• respiratory, postural, and abdominal exercises • strength exercises for the trunk, upper limbs, and lower limbs	MEP		M: Pre 67.9±18.9; Post 85.0±17.3, p=0.106 F: Pre 67.1±14.5; Post 81.7±18.7, p=0.007 ES (M)=0.94, ES (F)=0.87
				Lung volumes	Spirometry (%)	
				FEV_1		M: Pre 69.2±18.6; Post 71.1±18.4, p=0.598 F: Pre 69.5±25.7, Post 71.5±26.6, p=0.555 ES (M)=0.10, ES (F)=0.08
				FVC		M: Pre 78.2±17.6; Post 76.8±13.3, p=0.463 F: Pre 80.1±22.4, Post 81.4±27.2, p=0.964 ES (M)=0.09, ES (F)=0.05
Guimarães et al (2012)/Brazil	RCT	Heart failure: n=16	Duration: 16 weeks	Vital signs	CPET	
			Frequency: 60 min. group session 2days/wk Components:	HR rest (bpm)		EG: Pre 78±17; Post 76±13, p>0.05 CG: Pre 72±18; Post 71±18, p>0.05
		Intervention:	• warm-up and cool down -10 min.			ES= -0.05
		n=8; 62%male; 46±12yrs	• aerobic exercise – 30 min. walking on treadmill	HR max (bpm)		EG: Pre 135±27; Post 144±24, p>0.05 CG: Pre 125±23; Post 125±18, p>0.05
			• Pilates mat exercises – 20 min.			ES= -0.32
		Control: n=8; 81%male; 44±11yrs	strengthening, stretching, ROM, and balance exercises Components CG:	SBP rest (mmHg)		EG: Pre 106±16; Post 101±24, p>0.05 CG: Pre 113±24; Post 108±17, p>0.05 ES= 0.00
			• warm-up and cool down -10 min. • aerobic exercise – 30 min. walking on treadmill	SBP max (mmHg)		EG: Pre 125±17; Post 143±21, p>0.05 CG: Pre 134±21; Post 127±18, p>0.05 ES= -1.05
			• flexibility exercise • resistance exercise	DBP rest (mmHg)		EG: Pre 73±14; Post 67±17, p=0.02 CG: Pre 69±9; Post 67±12, p>0.05

			1 set of 10–15 repetitions of 8–10 exercises calisthenics			ES= -0.24
				DBP max (mmHg)		EG: Pre 68±19; Post 69±13, p>0.05 CG: Pre 64±15; Post 64±21, p>0.05 ES= -0.05
				Exercise tolerance	CPET	
				Peak VO_2 (mlO_2 /kg/min)		EG: Pre 20.9±6.6; Post 24.8 ± 6.0, p=0.001 CG: Pre 17.4±3.9; Post 18.3 ± 4.2, p>0.05 ES= 0.46, p=0.02
				Pulse O_2 (mlO_2/bpm)		EG: Pre 11.9±3; Post 13.8±3, p=0.003 CG: Pre 11.6±4; Post 12±4, p>0.05 ES= 0.35
				RER		EG: Pre 1.1±0.1; Post 1.1±0.1, p>0.05 CG: Pre 1.1±0.1; Post 1.1±0.1, p>0.05 ES= 0.00
				VE/VCO_2		EG: Pre 29±5; Post 29±4, p>0.05 CG: Pre 31±6; Post 32±6, p>0.05 ES= 0.15
				Time (minutes)		EG: Pre 12.8±2.5; Post 17.8±4, p< 0.001 CG: Pre 11.7±3.9; Post 14.2±4, p>0.05 ES= 0.55
Martins-Meneses et al (2014)/Brazil	CCT	Hypertension n=44	Duration: 16 weeks Frequency: 60 min group session 2days/wk Components:	Flexibility	Bank of wells test (cm)	EG: Pre 25.7±8.4; Post 30.0±7.4, p<0.05 CG: Pre 22.5±9.2; Post 22.4±9.4, p>0.05 ES=0.42, p<0.05
		Intervention: n=22	warm-up and cool down – 20 min.	Handgrip strength	Handgrip dynamometer (kg)	

	0%male;	Pilates mat exercises – 40 min.	Right hand		EG: Pre 27.3±5.6; Post 30.4±4.6, p<0.05
	51.8±4.3yrs	strengthening, stretching, range of motion,			CG: Pre 27.6±6.0; Post 27.2±5.8, p>0.05
		and balance exercises			ES=0.52, p<0.05
	Control:	Components CG: Usual Care	Left hand		EG: Pre 26.0±6.2; Post 29.8±5.3, p<0.05
	n=22				CG: Pre 25.9±5.8; Post 25.3±5.6, p>0.05
	0%male;				ES=0.63, p<0.05
	49.0±7.5yrs		Body composition	Anthropometric tape	
			BM (kg)		EG: Pre 79.0±14.8; Post 78.7±15.0, p>0.05
					CG: Pre 79.1±17.3; Post 79.9±17.2, p>0.05
					ES=-0.06, p>0.05
			BMI (kg/m^2)		EG: Pre 30.0±4.7; Post 29.6±4.8, p>0.05
					CG: Pre 30.2±6.3; Post 30.5±6.3, p>0.05
					ES=-0.1, p>0.05
			Waist circumference (cm)		EG: Pre 93.2±13.5; Post 89.9±13.2, p<0.05
					CG: Pre 93.5±16.0; Post 95.0±14.4, p>0.05
					ES=-0.27, p<0.05
			Hip circumference (cm)		EG: Pre 110.8±11.0; Post 107.9±10.1, p<0.05
					CG: Pre 109.0±14.1; Post 110.7±12.7, p>0.05
					ES=-0.31, p<0.05
			Vital signs	Oscillometric device (24h)	
			SBP (mmHg)		EG: Pre 125.6±18.3; Post 118.5±10.3, p<0.05
					CG: Pre 122.2±11.4; Post 125.1±13.4, p>0.05
					ES=-0.59, p<0.05
			DBP (mmHg)		EG: Pre 78.2±14.2; Post 74.9±9.4, p<0.05
					CG: Pre 76.5±8.4; Post 77.8±10.0, p>0.05
					ES=-0.35, p<0.05

				MBP (mmHg)		EG: Pre 94.0±15.3; Post 89.4±9.4, p<0.05 CG: Pre 91.8±8.9; Post 93.6±10.7, p>0.05 ES=-0.45, p<0.05
				HR (bpm)		EG: Pre 73.5±8.6; Post 75.7±9.1, p>0.05 CG: Pre 78.9±10.6; Post 78.0±10.1, p>0.05 ES=-0.26, p>0.05
				DP (bpm x mmHg)		EG: Pre 9263.3±1939.4; Post 8983.6±1376.4, p>0.05 CG: Pre 9646.8±1592.6; Post 9775.6±1643.0, p>0.05 ES=-0.2, p>0.05
Sung et al (2016)/Republic of Korea	RCT	Stroke: n=19 Intervention: n=10; 50%male; 66.8±5.7yrs Control: n=9; 56%male; 61.1±6.6yrs	Duration: 8 weeks Frequency: 60 min. supervised 3 days/wk, Components EG: · warm-up and cool down · breathing exercises · Pilates exercises 1 set of 8 repetitions · mobility and strengthening exercises · other exercises Charlie Chaplin exercises, swimming, heel squeeze and prone bridge CG: Usual Care	Static balance	Treadmill	
				Medial-lateral COP (mm)		EG: Pre 10.9±5.0; Post 7.1±2.2, p<0.05 CG: Pre 11.7±5.4; Post 16.1±6.1, p>0.05 ES=-1.36, p<0.05
				Anterior-posterior COP (mm)		EG: Pre 14.8±8.0; Post 10.5±3.7, p<0.05 CG: Pre 16.1±6.1; Post 16.8±5.0, p>0.05 ES=-0.67, p<0.05
				Medial-lateral velocity (mm/s)		EG: Pre 83.9±42.1; Post 66.5±26.6, p<0.05 CG: Pre 84.2±45.0; Post 86.7±41.9, p>0.05 ES=-0.41, p<0.05
				Anterior-posterior velocity (mm/s)		EG: Pre 122.0±47.6; Post 104.5±42.0, p<0.05 CG: Pre 130.5±45.8; Post 135.8±43.2, p>0.05 ES=-0.42, p<0.001
				Dynamic balance (Paretic Side)		
				Medial-lateral COP (mm)		EG: Pre 15.0±2.1, Post 12.0±1.4, p<0.01 CG: Pre 16.0±2.4; Post 16.3±2.4, p>0.05

						ES=-1.28, p<0.05
				Anterior-posterior COP (mm)		EG: Pre 27.0±3.2; Post 22.4±2.7, p<0.001 CG: Pre 26.2±3.7; Post 26.5±2.9, p>0.05 ES=-1.27, p<0.001
				Medial-lateral velocity (mm/s)		EG: Pre 88.6±33.5; Post 76.5±25.6, p<0.05 CG: Pre 91.8±39.8; Post 92.6±38.8, p>0.05 ES=-0.3, p<0.001
				Anterior-posterior velocity (mm/s)		EG: Pre 114.8±31.2; Post 98.3±25.2, p<0.01 CG: Pre 117.0±30.6; Post 117.1±29.1, p>0.05 ES=-0.46, p<0.001
				Dynamic balance (non-paretic Side)		
				Medial-lateral COP (mm)		EG: Pre 12.7±1.2; Post 10.4±0.8, p<0.001 CG: Pre 13.7±2.2; Post 14.2±1.9, p>0.05 ES=-1.43, p<0.001
				Anterior-posterior COP (mm)		EG: Pre 23.2±2.4; Post 18.2±1.2, p<0.001 CG: Pre 22.1±3.6; Post 22.9±3.3, p>0.05 ES=-1.71, p=<0.001
				Medial-lateral velocity (mm/s)		EG: Pre 79.0±28.3; Post 66.5±21.2, p<0.05 CG: Pre 86.0±27.2; Post 87.2±26.3, p>0.05 ES=-0.43, p<0.001
				Anterior-posterior velocity (mm/s)		EG: Pre 89.7±28.8; Post 73.2±17.9, p<0.05 CG: Pre 96.9±27.5; Post 97.0±25.1, p>0.05 ES=-0.53, p<0.01
Lim et al (2017)/Republic of Korea	RCT	Stroke: n=20 Intervention: n=10	Duration: 8 weeks Components EG:	Functional status	TUG (seconds)	EG: Pre 22.6±5.7; Post 19.2±5.8, p<0.05 CG: Pre 19.2±5.4, Post 21.7±6.4, p<0.05 EG vs CG p<0.05

60%male;	Frequency: 60 min. supervised 3 days/wk			ES=-0.82
63.2±7.9yrs	breathing exercises			
	Pilates exercises			
Control:	8 sets	Vital signs	CPET	
n=10	spine mobility exercises	HR rest (bpm)		EG: Pre 84.1±16.6; Post 76.5±14.5, p<0.05
50%male;	upper limb exercises			CG: Pre 83.3±17.3, Post 85.4±16.6, p<0.05
62.1±6.7yrs	lower limb strengthening exercises			EG vs CG p<0.05
	EG and CG: conventional stroke rehabilitation program 30 min 5 days/wk for 8 weeks			ES=-0.49
		Exercise tolerance	CPET	
	joint mobility	VO_2 max (ml/min)		EG: Pre 819.3±251.4; Post 964.8±244.2, p<0.05
	muscle strengthening			CG: Pre 1048.8±420.5, Post 1027.3±416.5, p<0.05
	walking exercise			EG vs CG p<0.05
				ES=0.40
		VO_2 max per kg (ml/kg/min)		EG: Pre 12.1±2.9; Post 14.3±2.5, p<0.05
				CG: Pre 14.7±4.7, Post 14.4±4.7, p<0.05
				EG vs CG p<0.05
				ES=0.53

Data are presented as mean±standard deviation;

NCDs: Noncommunicable diseases; RCT: Randomized control trial; EG: Experimental group; CG: Control group; ES: Effect size; HbA1c: Glycated haemoglobin; DID: Daily insulin doses; HDL: High density lipoprotein; LDL: Low density lipoprotein; T col: Total cholesterol; TG: Triglyceride; 6MWT: 6-minute walk test; 6MWD: 6-minute walk distance; PG: Pilates group; CEG: Combined exercise group; HEG: Home exercise group; NR: not reported. Authors were contacted and did not reply; ROM: Range of motion; NB: Natural breathing; DB: Diaphragmatic breathing; PB: Pilates breathing; %RCi: Percent rib cage inspiratory contribution to tidal volume ratio; SpO2: Peripheral oxygen saturation; M: Male; F: Female; MIP: Maximum Inspiratory Pressure; MEP: Maximum Expiratory Pressure; FEV1: Forced expiratory volume in 1 second; FVC: Forced vital capacity; CPET: Cardiopulmonary exercise test; HR: Heart rate; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; VO2: oxygen consumption; RER: Respiratory exchange ratio; VE/VCO2: Minute ventilation − carbon dioxide production relationship; CCT: Non randomized controlled clinical trial; BM: Body mass; BMI: Body mass index; MBP: Mean blood pressure; DP: Double product; COP: centre of pressure.

* Constant Murley score is a mixed measure but it was allocated to clinical outcomes as they account for 65 points out of 100 points of the measure.

Table 3 - Effects of Pilates in noncommunicable diseases - patient reported outcomes (PROs) and outcome measures

Author (Year)/Country	Study Design	Participants	Intervention	Measures	Outcome Measures	Key Findings
Torabian et al (2013)/Iran	2 groups pre-post design	Type 2 Diabetes: n=70 Intervention: n=35; 0%male [30-70] yrs Control: n=35; 0%male [30-70] yrs	Duration: 8 weeks Frequency: 60 min. supervised 2d/wk Components EG: • warm-up and cool down - 5 min. ○ stretching exercises • Pilates exercises - 50 min. ○ 10 to 80 repetitions CG: Usual Care	Symptoms	GHQ-28	
				Physical symptoms		EG: Pre 43.1±2.1; Post 4.3±1.8, p=0.001 CG: Pre 12.2±3.1; Post 11.9±2.7, p=0.23 EG vs. CG p=0.01 ES=-12.70
				Anxiety		EG: Pre 11.0 ±2.0; Post 5.9±2.2, p=0.04 CG: Pre 10.6±3.3; Post 0.7±2.6, p=0.11 EG vs. CG p= 0.003 ES= -1.52
				Depression		EG: Pre 11.1±2.6; Post 6.4±2.0, p=0.01 CG: Pre 11.5±2.9; Post 11.3±3.0, p=0.47 EG vs. CG p=0.04 ES=-1.38
				Social dysfunction	GHQ-28	EG: Pre 13.0±2.3; Post 6.2±2.2, p=0.02 CG: Pre 12.4±3.5; Post 11.5±2.9, p=0.50 EG vs. CG p=0.001 ES= -1.73
				Total score		EG: Pre 47.2±9.1; Post 22.8±8.2, p=0.002 CG: Pre 46.6±12.9; Post 45.5±11.0, p=0.24 EG vs CG p= 0.003 ES= -1.82
Yucel and Uysal (2015)/Turkey	RCT	Type 2 diabetes: n=45	Duration: 12 weeks Frequency: 45 to 70 min. supervised 3 days/wk	Symptoms	VAS	

		Intervention: n=24; 0%male; 58.5±7yrs Control: n=21; 0%male; 53.5± 9yrs	Components EG: • warm-up and cool down • stretching exercises; • basic aerobic pilates CG: Usual Care	Pain		EG: Pre 3.0±4.0; Post 2.0±2.0, p=0.001 CG: Pre 3.0±3.0; Post 3.0±2.0, p=0.308 ES=-0.27
				Fatigue		EG: Pre 5.0±2.0; Post 4.0±1.0, p=0.001 CG: Pre 4.50±1.0; Post 4.0±2.0, p=0.42 ES=-0.25
				Symptoms	SF-36	
				Mental health		EG: Pre 29.0±5.0; Post 35.0±3.0, p=0.001 CG: Pre 29.0±11.0; Post 35.0±1.0, p=0.132 ES=0.00
				Physical Health		EG: Pre 40.0±3.0; Post 41.0±4.0, p=0.120 CG: Pre 40.0±0.0; Post 41.0±4.0, p=0.42 ES=0.00
				Symptoms	HADS	
				Anxiety		EG: 8.0±3.0; Post 7.0±3.0, p=0.023 CG: Pre 8.0±1.0; Post 7.0±1.0, p=0.162 ES=0.00
				Depression		EG: Pre 9.0±2.0; Post 8.0±2.0, p=0.019 CG: Pre 9.0±2.0; Post 8.0±1.0, p=0.08 ES= 0.00

Eygor et al (2010)/Turkey	RCT	Breast Cancer: n=41
		
		Intervention: n=27; 0%male; 48.5±7.6yrs
		
		Control:
			Duration: 8 weeks
			Frequency: 60 min. supervised and 20-30 min. unsupervised 3 days/wk,
			Components EG:
			• warm-up and cool down
			  ○ breathing and stretching exercises
			• pilates exercises
			  ○ 2 sets of 10 repetitions
			• education session - 30 min.
				Symptoms		

				Fatigue	BFI	EG: Pre 6.6±4.1; Post 5.6±4.7, p= 0.14 CG: Pre 7.7±5.7; Post 6.5±4.4, p=0.82 EG vs CG p= 0.66 ES= -0.03
				Depression	BDI	EG: Pre 7.4±5.8; Post 5.6±6.4, p= 0.01 CG: Pre 9.5±12.1; Post 6.8±9.5, p=0.25 EG vs CG p=0.47 ES=-0.09

		n=15; 0%male; 49.73±8.7yrs	• unsupervised exercises from a booklet - once a day • unsupervised walk – 20 to 30 min. ○ 3days/wk Components CG: • education session - 30 min. • unsupervised exercises from a booklet - once a day • unsupervised walk – 20 to 30 min. ○ 3days/wk	Quality of life	EORTC QLQ-C30	
				Functional QoL		EG: Pre 77.1±15.0; Post 83.3±14.7, p=0.03 CG: Pre 76.7±21.7; Post 78.0±20.5, p=0.53 EG vs CG p=0.33 ES=0.23
				Symptoms QoL		EG: Pre 19.0±12.2; Post 20.9±21.5, p=0.43 CG: Pre 23.2±23.9; Post 13.2±10.0, p= 0.21 EG vs CG p=0.48 ES=0.53
				Global QoL		EG: Pre 70.2±20.6; Post 77.0±21.8, p=0.19 CG: Pre 62.6±29.3; Post 63.8±23.8, p=0.91 EG vs CG p=0.79 ES=0.20
				Quality of life	EORTC QLQ-BR23	
				Functional QoL		EG: Pre 77.8±16.6; Post 84.4±10.5, p= 0.04 CG: Pre 73.27±20.1; Post 75.8±10.6, p=0.85 EG vs CG p=0.26 ES=0.22
				Symptoms QoL		EG: Pre 21.1±15.3; Post 17.4±18.2, p=0.20 CG: Pre 23.0±20.2; Post 19.0±10.6, p=0.18 EG vs CG p=0.31 ES=0.01
Zengin et al (2016)/Turkey	RCT	Breast Cancer: n=56 PEG: n=18; 0%male; 46.2 ± 11.2yrs	Duration: 8 weeks Frequency: 45 min. supervised 3 days/wk Components PG: • teaching of key elements of Pilates • Pilates-based mat exercises • Pilates-based theraband exercises	Symptoms	VAS	
				Pain in motion		PEG: Pre 5.0±2.0; Post 1.7±1.6, p <0.001 CEG: Pre 4.6±1.6; Post 1.3±1.7, p<0.001 HEG: Pre 4.3±2.2; Post 2.1±2.3, p<0.001 PEG vs CEG vs HEG p=0.109 ES=0.08

		CEG:
		n=18; 0%male;
		51.9 ± 8.0yrs
		
		HEG:
		n=19; 0%male;
		51.5 ± 13.8yrs
			Components CEG:
			• Stretching
			• ROM
			• Shoulder strengthening exercises
			• breathing exercises
			
			Duration; 8 weeks
			Frequency: 3days/wk unsupervised
			Components HEG:
			• Individual exercise program taught by a physiotherapist.
			○ Stretching
			○ ROM
			○ Shoulder strengthening exercises
			○ breathing exercises
				Pain at rest		PEG: Pre 2.6±2.5; Post 0.5±1.0, p=0.004
						CEG: Pre 1.6±1.8; Post 0.2±0.6, p=0.002
						HEG: Pre 2.0±2.3; Post 0.2±0.7, p=0.005
						PEG vs CEG vs HEG p=0.897
						ES=0.0

				Functional status	DASH	PEG: Pre 38.8±17.2; Post 23.8±13.4, p<0.001 CEG: Pre 31.4±11.9; Post 19.4±12.0, p<0.001 HEG: Pre 38.9±20.1; Post 32.1±20.2, p=0.046 PEG vs CEG vs HEG p=0.002 ES=0.21
Sener et al (2017)/Turkey	RCT	Breast Cancer n=60 Intervention: n=30; 0%male; 53.2±7.7yrs Control: n=30; 0%male; 54.0±12.6yrs	Duration: 8 weeks Frequency: 3 days/wk Components EG: • Pilates exercises • Home program – every day ○ manual lymphatic drainage training, wall extension, and Wand exercises Components CG: • Core stabilization exercises • Home program – every day ○ Daily living activities with core protection ○ manual lymphatic drainage	Symptoms Pain	VAS	EG: Pre 3.5±3.2; Post 0.7±0.8, p<0.01 CG: Pre 2.3±3.3; Post 0.9±1.4, p=0.02 EG vs CG p=0.51 ES=-0.44
				Anxiety	SAA	EG: Pre 24.8±8.0; Post 19.7±3.7, p <0.01 CG: Pre 27.6±9.1; Post 26.2±8.1, p=0.04 EG vs CG p<0.01 ES=-0.40
				Quality of life	EORTC QLQ-BR23	EG: Pre 32.4±10.2; Post 38.5±8.4, p=0.04 CG: Pre 34.1±9.6; Post 38.4±7.5, p=0.02 EG vs CG p=0.94 ES=0.16

	○ shoulder exercises ○ skin care	Functional status	DASH	EG: Pre 44.2±15.3; Post 38.0±15.0, p <0.01 CG: Pre 34.8±12.0; Post 32.2±12.1, p <0.01 EG vs CG p=0.39 ES=-0.21

Data are presented as mean±standard deviation

EG: Experimental group; CG: Control group; ES: Effect size; GHQ-28: General health questionnaire – 28; VAS: Visual analogue scale; SF-36: 36-item short-form health survey; HADS: Hospital anxiety depression scale; BFI: Brief fatigue inventory; BDI: Beck depression index; EORTC QLQ-C30: European organization for the research and treatment of cancer quality of life questionnaire; QoL: quality of life; EORTC QLQ-BR23: European organization for the research and treatment of cancer quality of life questionnaire breast cancer module 23; DASH: Disabilities of the arm, shoulder, and hand scale; PEG: Pilates exercice group; CEG: combined exercise group; HEG: home exercise group; SAA: Social appearance anxiety (SAA) Scale

Table 4 -Best-evidence synthesis of the effects of Pilates in noncommunicable diseases

Outcome	Studies	Level of evidence	Direction of effect
Symptoms	[70, 71, 74, 75, 79]	2	Pilates equal to other interventions
Vital signs	[72, 76, 78, 80]	4	conflicting evidence
Metabolic parameters	[81]	3	Pilates equal to usual care
Body composition	[76]	3	favours Pilates
Muscle strength	[71, 73, 76, 79, 81]	2	Pilates equal to other interventions but favours Pilates over usual care
Respiratory function	[72, 73]	3	Pilates equal to other interventions
Functional Status	[71, 79, 80]	4	conflicting evidence
Exercise tolerance	[70, 78, 80]	1	favours Pilates
Balance	[77]	3	favours Pilates
Flexibility	[70, 71, 76, 79, 81]	4	conflicting evidence
HRQoL	[70, 79]	2	Pilates equal to other interventions
Social support	[75]	3	favours Pilates

HRQoL: Health-related quality of life

Level of evidence: 1 – strong; 2 – moderate; 3 – limited; 4 – conflicting; 5 – no evidence.

Appendix 1

The following electronic databases were searched for potential studies: Cochrane Library (1999-2017), EBSCO (1974-2017), PubMed (1996-2017), Science Direct (1997-2017), Scopus (1960-2017) and Web of Science (1900-2017) on the 15th of November 2016. Additional searches were performed in weekly automatic updates retrieved from the databases until November 2017. The search terms used were organized using the PICOT (Population, Intervention, Comparison, Outcome and Time) framework[102]:

P: Chronic respiratory diseases (COPD, asthma, cystic fibrosis, bronchiectasis); Chronic cardiovascular diseases (hypertension, heart failure, coronary artery disease, vascular disease, cardiac arrhythmias, stroke); diabetes; cancer.
I: pilates; mat pilates; pilates method; pilates-based rehabilitation
C: respiratory physiotherapy; respiratory physical therapy; physiotherapy; physical therapy; exercise; exercise training; pulmonary rehabilitation; respiratory rehabilitation; cardiac rehabilitation; breathing exercises; airway clearance techniques; strength; stretch; flexibility; balance; diaphragmatic breathing; physical activity; aerobic exercise; yoga; yogasana; tai-chi; walking; running; hiking; dancing; nordic-walking; hydrotherapy; swimming; meditation; psychoeducation; education and psychosocial support
O: breathing pattern; lung volumes; respiratory rate; chest expansion; symptoms; dyspnea; fatigue; pain; depression; anxiety; neuromotor; function*; exercise tolerance; force; strength; functional capacity; balance; flexibility; body composition; health; quality of life; well-being
T: not applicable

Typical Search

[(“chronic respiratory disease” OR “chronic lung disease” OR “COPD” OR “chronic obstructive pulmonary disease” OR “asthma” OR “cystic fibrosis” OR “chronic cardiovascular disease” OR “heart failure” OR “hypertension” OR “atherosclerosis” OR “coronary artery disease” OR “valvular disease” OR “cardiac arrhythmias” OR “stroke” OR “diabetes” OR “cancer”) AND (“breathing pattern” OR “respiratory pattern” OR “lung volume” OR “respiratory volume” OR “lung capacity“ OR “respiratory rate” OR “chest expansion” OR “thoracic expansion” OR “chest extension” OR “symptoms” OR “metabolic” OR “dyspnea” OR “dyspnoea” OR “fatigue” OR "pain" OR "depression" OR "anxiety" OR "neuromotor" OR "function*" OR "functional capacity" OR "capacity" OR "exercise tolerance" OR "exercise capacity" OR "aerobic capacity" OR "aerobic tolerance" OR "resistance" OR "force" OR "strength" OR "balance" OR "flexibility" OR "stretch" OR "body composition" OR "BMI" OR "body mass index" OR "fat mass" OR "health" OR "quality of life" OR "life quality" OR "well-being" OR "questionnaire*" OR "interview*") AND ("pilates" OR "pilates-based rehabilitation")].