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META-ANALYSIS

Effects of Pilates method in physical fitness on older adults. A systematic review

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Abstract Pilates method is employed for physical and mental conditioning. Elderly people could be benefited from a patterned and regulated conditioning work based on Pilates method. We performed a systematic review to assess the evidence on the effects of Pilates method in physical fitness on older adults. Our search included the following databases: MEDLINE-PubMed, Scopus and CINAHL Plus with Full Text via EBSCO and SPORTDiscus databases (up to April 2014). A summary of the results was performed using a best evidence synthesis and was reported according to the systematic review method proposed by Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement. The Physiotherapy Evidence Database (PEDro) scale was used to assess the methodology quality of selected studies. Seventeen experimental studies were included in this review. Fourteen were randomized controlled trials (RCT) and three clinical controlled trials (CCT). Quality scores according to PEDro indicate low quality of the included studies (range 1–6, mean 3.8±1.2). The most studied components related to physical fitness were neuromotor fitness (n=11), muscle strength (n=8), cardiorespiratory endurance (n=4), body composition (n=4) and flexibility (n=4). Results indicate that Pilates method seems to present positive effects in neuromotor fitness, especially in static and dynamic balance. Related to the other components of physical fitness (cardiorespiratory endurance, muscle strength, body composition and flexibility), contradictory results were observed. The Pilates method indicates to be an appropriate exercise modality in order to improve balance on older adults. Nevertheless, more intervention research is needed to build a solid knowledge base about the health benefits of Pilates method on older people, especially regarding the other components of physical fitness.

Keywords Physical activity · Aged · Health · Pilates-based exercises

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Introduction

Over the last century, the number and proportion of older adults in the world's population have largely increased due to the socio-economic development and the provision of better medical services [31]. This general increase in life expectancy, although positive, promotes the development of health problems in elderly population. In particular, it is now widely understood that physiological and physical changes could be related to metabolic problems like diabetes mellitus and the loss in bone density [40], the decline in muscle tension [21] and cardiorespiratory endurance [9] in the ageing process, something that could cause impairments in daily life.

In older adults, physical fitness directly influences functional independence [15]. Physical activity (PA) is considered as one of the most important health indicators yielding benefits for all the major groups of age, especially older adults. In such age group people, the benefits could be related to the improvement in physical fitness and the prevention of functional loss [20]. The American College of Sports Medicine [2] recommends, as part of a guiding on basic exercises, that the elderly should use exercise programs focused on four physical fitness components (cardiorespiratory endurance, muscle strength, flexibility and neuromotor fitness). Pilates method is an exercise program that was developed in the early twentieth century by Joseph Hubertus Pilates with the goal of improving general body flexibility and health, core strength and posture and to coordinate movement with the breath [28]. Pilates method emphasizes proper control of breathing, axial elongation and central control, movement along the spinal column, efficiency of the movement provided by shoulder joint and cervicothoracic spine organization, limbs alignment, and integration of the core [3].

In recent years, the body of research on the effects of Pilates method in physical fitness of older adults has grown exponentially. It suffices to say that 80 % of them have been made between 2010 and 2014. In terms of physical fitness, older people could be benefited from a patterned and regulated conditioning work based on Pilates method with regard to flexibility [23, 26], stability and static and dynamic balance [4, 6, 8, 19, 22, 23, 36, 38, 43], general strengthening [12, 13, 33, 38, 41, 45], and particularly, strengthening of abdominal muscles [10], reduction of joint restrictions and the increase of range of joint motion [25, 33, 38]. All this can lead to an increase in physical function [8, 45] and personal autonomy in older adults [43].

There are currently six systematic reviews on the effectiveness of Pilates method in relieving pain and improving function in adults with low back pain [1, 5, 27, 30, 37, 39] and one on the effects of Pilates method on healthy people [11]. This later includes an older sample, and the average sample age of the analyzed studies is under 65 years. There is only one systematic review analyzing the effects of different physical exercise programs on muscle strength for balance, functional performance and fall prevention in elderly people, and such publication includes the analysis of five studies on Pilates method [18].

The results presented by the different studies on Pilates method effects on older adults are positive, especially regarding improvements in physical fitness. However, those studies are relatively recent, and the benefits they provide should be contrasted with more studies. The objective of this study was, therefore, to systematically review the literature evidence in order to analyze the effectiveness of the Pilates method, in itself or combined with other types of intervention or other types of exercises in physical fitness components (cardiorespiratory endurance, muscle strength, body composition, flexibility and neuromotor fitness) on older adults.

Methods

Data sources and search

A systematic literature search was conducted from December 2012 to April 2014. The following electronic databases were searched: MEDLINE-PubMed (1980–present), Scopus (1980–present), CINAHL Plus with Full Text via EBSCO (1982–present), and SPORTDiscus (1980–present).

A specific search was conducted in the Cochrane Library to exclude the existence of reviews with the same objective as the present one. For the purpose of this review, physical fitness [2, 16] was defined as cardiorespiratory endurance (ability to perform large muscle, dynamic, moderate-to-high intensity exercise for prolonged periods, assessed by maximal or submaximal exercise tests), muscle strength (ability of a muscle to exert force), body composition (relative amount of muscle, fat, bone and other vital parts of the body), flexibility (range of motion of a specific joint) and neuromotor fitness (motor skills like balance, coordination, gait and agility).

The following search terms were applied [(older OR aging OR older adults OR elderly OR older people OR elderly people) AND (Pilates OR Pilates method) AND (cardiorespiratory fitness OR respiratory fitness OR aerobic capacity OR aerobic fitness OR aerobic exercises OR physical activity OR fitness OR physical fitness OR physiotherapy OR muscle strength OR body composition OR body fat OR flexibility OR neuromotor fitness OR balance OR coordination OR gait OR agility)].

Inclusion criteria and selection process

Based on the article titles and abstracts, when available, the identified reports were initially evaluated for inclusion/exclusion using the following inclusion criteria:

- Subjects: greater than or equal to 65 years old
- Study design: true and quasi-experimental designs [24, 34]
- Assessed physical fitness (including at least one of the following parameters: cardiorespiratory endurance, muscle strength, body composition, flexibility and neuromotor fitness) and Pilates method on physical fitness
- Intervention time: greater or equal to 4 weeks [33] (the minimum time in which positive changes related to the practice of Pilates method can be observed)

Articles published before 1980, not providing quantitative data on physical fitness and not individualizing the results of participants, as well as case reports and expert opinions, were excluded. This review was reported according to the systematic review method proposed by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) [29].

Study selection

Two reviewers (G.R. and J.C.) independently read all abstracts and classified them as excluded or potentially included. A third reviewer (I.M.) was consulted if there was disagreement between the two reviewers. The studies were selected based on their titles and abstracts; when the abstracts were relevant to the purpose of the review, the full-text article was read carefully to decide its inclusion. Reviewers applied the inclusion criteria after reading the potentially included studies.

Data extraction

Selected studies were subjected to analysis and methodological quality assessment by two reviewers independently (G.R. and J.C.), who extracted the data according to a common table format including information on study identification, purpose, sample and subjects, intervention program, outcome measurements and results. Studies were harmonized in terms of the style and level of details by two reviewers. In a meeting, the reviewers tried to accomplish agreement on differences in scoring. When disagreement persisted, the third reviewer (I.M.) made the final decision.

Quality assessment

The methodological quality of the trials was assessed using the PEDro scale [32]. The PEDro scale intends to evaluate four fundamental methodological aspects of a study such as random process, blinding technique, group comparison and data analysis process. The PEDro scale is based on a Delphi list developed by Verhagen et al. [46] that includes 11 items: specified eligibility criteria, random allocation, concealed allocation, baseline comparability, blinded subjects, blinded therapists, blinded assessors, adequate follow-up, intention-to-treat analysis, between-group comparisons, and point estimates and variability. The reliability of this scale was evaluated with acceptable results in intraclass correlation coefficients (ICC) equals to 0.56 (95 % CI=0.47–0.65) for ratings by individuals and ICC for consensus ratings equal to 0.68 (95 % CI=0.57–0.76) [32].

Assessment of the quality of trials in the PEDro database was performed by two trained independent raters, and disagreements were resolved by a third rater [42]. The PEDro scale has been used in previous Pilates systematic reviews [1, 11, 27]. The PEDro scale scores range from 1 to 10; higher PEDro scores correspond to higher method quality. Because we do not know of the published validated cut-off scores for the PEDro scale, the following criteria were used to rate method quality: A PEDro score of less than 5 indicates low quality, and a PEDro score of 5 or higher indicates high quality [11].

Data syntheses and analysis

The experimental studies were divided into two groups, those comparing a Pilates method group to an inactive group or those comparing a Pilates method group to other exercise method group. The strength of the scientific evidence was measured by using the best evidence synthesis (BES) [44]. This rating system takes into account the number, methodological quality and consistency of outcomes of the studies in five levels of evidence: (1) strong evidence, provided by generally consistent findings in multiple (≥2) high-quality studies, (2) moderate evidence, provided by generally consistent findings in one high-quality study and one or more low-quality studies or in multiple low-quality studies, (3) limited evidence, when only one study is available or findings are inconsistent in multiple (≥2) studies, (4) conflicting evidence, provided by conflicting findings in case–control studies (<75 % of the studies reported consistent findings) and (5) no evidence, when no case–control studies are found [44].

Results

Study selection

The databases search identified 81 records. After duplicates removal, 62 records were screened for relevant content. During the title and abstract screening, 37 articles were excluded. Twenty-five full-text potentially relevant articles were assessed, and eight of them were excluded due to the lack of a control group. Therefore, a total of 17 studies were included in this review (Fig. 1).

Method quality

The range of values in PEDro scale was from 1 to 6 (mean 3.8 ±1.2; median, 4; mode, 4). Twelve studies scored less than 5 and the rest of the studies (n=6) scored 5 or higher, something that indicates a mix between high-quality and low-quality studies. The year of publication does not appear to be an element that influences the quality of the studies, being the low-quality studies published from 2003 to 2013, and the high-quality studies published from 1998 to 2012 (see Table 1). The criteria that are most likely met according to statistical issues are “Point Measure and Variability” (n=16) and “Groups Similarity at baseline” (n=14). The criteria “blind subject” and “blind therapist” were not met in any of the analyzed studies, while the criterion “blind assessor” was met in only one study (Table 1).

Study characteristics

All the studies analyzed whose valued physical fitness were randomized controlled trials (n=14) or clinical controlled trials (n=3). Four studies included information on cardiorespiratory endurance, eight on muscle strength, four on body composition, four on flexibility and 11 on neuromotor fitness. None of the studies valued the five components of physical fitness. Just in one study [45], four of the components (neuromotor fitness, muscle strength, flexibility and cardio-

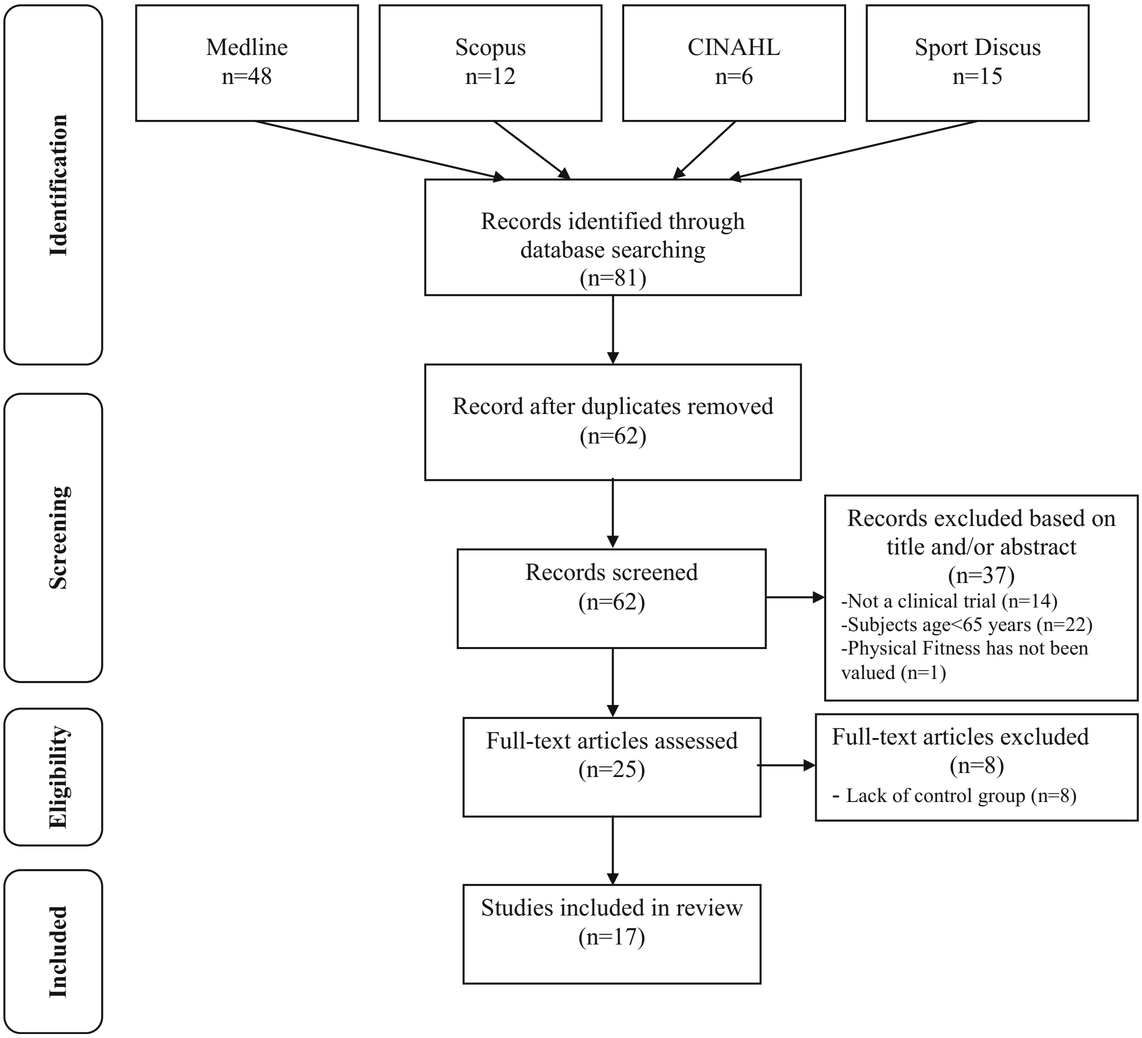

Fig. 1 PRISMA flowchart of the included studies

respiratory endurance) were valued. The majority of them (n=12) valued one or two components of physical fitness. A total of 746 old people have been included in the different analyzed studies, and the average age in the majority of them (n=14) was between 65 and 70 years. Only in two studies the average age was over 70 years.

All of the studies were controlled trials, and 16 of them had a pre–post-test design, while only one study had intermediate assessment [6]. None of the analyzed studies made a follow-up of the participants' physical fitness once the intervention with Pilates method had finished. Sample sizes were small, with a range from 6 to 30. Eleven studies enrolled only women (n=11), while six studies enrolled men and women. All studies used the Pilates method as the study intervention modality. Control groups were inactive in 10 studies. In four studies, Pilates method was compared with passive range of motion (ROM) exercises, aqua fitness class, unspecific program of physical education and unstable support surface exercises. In the remaining three studies, Pilates method was compared with inactive control groups and a third intervention group (strength and flexibility program, aqua fitness class and a program combining aqua fitness and Pilates method. The duration and frequency of Pilates method interventions ranged from 4 to 26 weeks and from one to three times per week. The total intervention time ranged between 10 and 78 h. In eight studies, the Pilates method interventions were performed on the mat, in three by means of different Pilates' apparatus, in one combining mat exercises and Pilates' apparatus, and in five, any specification was given (Table 2).

Physical fitness

Cardiorespiratory endurance

Cardiorespiratory endurance was valued only in four of the 17 studies included in this review. The measurement tools were the 6-min walking test [17, 38], the measurement of heart rate in resting [35] and by means of the Fullerton Functional

Table 1 PEDro scale rating

Reference	Eligibility criteria	Random allocation	Concealed allocation	Groups Similar at baseline	Blind subject	Blind therapist	Blind assessor	Follow-up	Intention-to-treat analysis	Between-group comparisons	Point measure and variability	PEDro score
Hall [19]	0	1	0	1	0	0	0	0	1	1	1	5
Mallery et al. [33]	1	1	0	1	0	0	0	1	0	0	1	4
Rodrigues et al. [41]	0	1	0	1	0	0	0	0	0	1	1	4
Rodrigues et al. [43]	0	1	0	1	0	0	0	0	0	1	1	4
Irez et al. [23]	1	1	0	1	0	0	1	0	0	1	1	5
Bird et al. [6]	0	1	0	1	0	0	0	1	1	1	1	6
Boguszewski et al. [8]	0	0	0	0	0	0	0	0	0	1	1	2
Coriolano et al. [4]	0	1	0	1	0	0	0	0	1	1	1	5
Fourie et al. [13]	0	1	1	1	0	0	0	0	0	1	1	5
Plachy et al. [38]	0	1	0	0	0	0	0	0	0	1	1	3
Mokhtari et al. [36]	1	1	0	1	0	0	0	0	0	0	1	3
Fernández y Benítez [12]	0	0	0	1	0	0	0	0	0	0	0	1
Fourie et al. [14]	0	1	1	1	0	0	0	0	0	0	1	4
Gildenhuys et al. [17]	0	1	0	1	0	0	0	0	0	1	1	4
Marinda et al. [35]	0	1	1	0	0	0	0	0	0	1	1	4
Vécseyné et al. [45]	0	1	0	1	0	0	0	0	0	1	1	4
Hyun et al. [22]	1	0	0	1	0	0	0	0	0	1	1	3
Total	4	14	3	14	0	0	1	2	3	13	16	

Table 2 Summary of studies on Pilates method and older adults

Reference	Design	Intervention focus	Participants	Mean age±SD (range) years	Main session content (E/C)	Intervention (Wk/f/min)	Total Intervention Time for E (hr)	Measurement tools	Findings
Hall [19]	Pre-post-test	To improve balance and gait	EG1=9 (M/F) EG2=9 (M/F) CG=6 (M/F)	69.5±4.1	EG1=strength and flexibility program EG2=Pilates method CG=No exercise	EG1=10/2/60 EG2=10/2/60	EG1=20 EG2=20	KAT and BBS.	Significant differences were observed on static balance on the KAT (p=0.0028) for the three groups, with EG2 improving more than EG1. All three groups also presented a significant time effect on the BBS (p=0.009).
Mallery et al. [33]	Pre–post-test	To improve leg strength with effective procedure and safe posture	EG=19 (5 M/14 F) CG=20 (11 M/9 F)	EG=82.7±8.5 CG=81.4±6.1	EG=resistance exercise program (using principles of the Pilates method) CG=passive ROM exercises	EG=4/3/30-40 (10 repetitions per exercise)	EG=7.24	Primary outcome measurements: participation and adherence. Other measurements: MMSE and 1RM for single leg knee extension.	Significant improvements in participation (p<0.005) and adherence (p<0.05) in ROM exercise group.
Rodrigues et al. [41]	Pre–post-test	To improve strength and flexibility	EG=27 (F) CG=25 (F)	EG=66.9±5; CG=65.2±3.9	EG=Pilates method CG=No exercise	EG=8/2/60	EG=16	GDLAM	Significant improvements for CG in 10-m walking (p<0.05) and significant improvements for EG in 10-m walking (p<0.001), get up from a sitting position (p<0.01), get up from a lying position (p<0.001), dress and undress a T-shirt (p<0.01) and get up from a chair and move around at home (p<0.01).
Rodrigues et al. [43]	Pre–post-test	To improve personal autonomy, static balance and quality of life	EG=27 (F) CG=25 (F)	66.0±4.0 (60–78)	EG=Pilates method CG=No exercise	EG=8/2/60	EG=16	Functional autonomy: GDLAM. Static balance: Tinetti test.	Significant post-test differences for EG in balance (p<0,001) and General Index of GDLAM (p<0,001).
Irez et al. [23]	Pre–post-test	To improve strength, flexibility, reaction time and dynamic balance	EG=30 (F) CG=30 (F)	EG=72.8±6.7 CG=78.0±5.7	EG=Pilates method CG=No exercise	EG=12/3/60	EG=36	Dynamic stability measurement platform. Reaction time: with a device using light and sound stimuli. Muscle Manual Tester. Flexibility: Sit-and-reach test. Number of falls.	Significant improvement for EG in dynamic balance (p<0.05), flexibility (sit and reach) (p<0.05), muscle strength (p<0.05), reaction time (p<0.05) and number of falls (p<0.05).
Bird et al. [6]	Pre, mind-post-test	To improve balance and leg strength	EG1=17 (M/F) CG1=15 (M/F) EG2=14 (M/F) CG2=13 (M/F)	EG1+CG1=67.2±6.6 EG2+CG2=67.3±6.5	EG=Pilates method CG=Usual activities	EG1=5/3/60 EG2=5/3/60	EG1=15 EG2=15	ML balance sway range with AMTI force platform. FSST. TUG. A spring-based measurement system developed as part of a battery of fall risk assessment tests (strength for knee extensors and ankle dorsiflexors).	Significant improvements in static and dynamic balance for EG (p<0.001) and in ML sway range on a foam cushion with eyes opened (p=0.001) and eyes closed (p<0.001), but not in lower-limb strength. No significant

Table 2 (continued)

Reference	Design	Intervention focus	Participants	Mean age±SD (range) years	Main session content (E/C)	Intervention (Wk/f/min)	Total Intervention Time for E (hr)	Measurement tools	Findings
									between-group differences (EG/CG) in any variable.
Boguszewski et al. [8]	Pre–post-test	To improve level of physical fitness and health	EG1=15 (F) EG2=10 (F)	EG1=65.9±7.2 EG2=65.9±5.0 (55–76)	EG1=Pilates method; EG2=Water-aqua fitness.	EG1=10/1/90 EG2=10/1/90	EG1=15 EG2=15	TUG. Test for strength and endurance of lower limbs: walking up the stairs. Test for strength of upper limbs: bending forearms. Test for suppleness of the lower body part: "reach to the toe". STAI.	Significant improvements for aqua fitness group in strength and endurance of lower limbs (p=0.014) and upper limbs (p=0.038) tests. No significant progress in TUG, flexibility of lower part of body and STAI for both groups was observed.
Coriolano et al. [4]	Pre–post-test	To improve balance	EG=19 (9 M/10 F) CG=20 (10 M/10 F)	EG=69.6±3.1 CG=69.7±2.9 (65–74)	EG=Pilates method CG=unspecific program Physical Education.	EG=10/2/60 CG=10/2/60	EG=20 CG=20	The balance test ("Gleichgewichtstest"—GGT).	Significant improvements in body balance for EG (p<0.01)
Fourie et al. [13]	Pre–post-test	To improve muscular strength and muscular endurance	EG=25 (F) CG=25 (F).	EG=65.3±5.0 CG=66.1±4.7	EG=Mat Pilates method CG=No exercise	EG=8/3/60	EG=24	Upper body muscular strength: number of arm curls in 30″ using a 2.5-kg dumbbell. Lower-body muscular strength: number of times in 30″ could stand up from a seated position. Muscular endurance: number of squats until fatigue.	Significant improvements for experimental group in upper and lower-body muscular strength, and muscular endurance (p<0,001) and significant improvements for control group in upper and lower body muscular strength (p<0.05).
Plachy et al. [38]	Pre–post-test	To improve stretching, strength, flexibility and balance	EG1=15 (F) EG2=15 (F) CG=12 (F)	EG1=66.2±3.8 EG2=67.1±5.9 CG=68.2±3.2 (60–78).	EG1=3 Pilates method EG2=2 aqua-fitness class+1 Pilates method class. CG=No exercise	EG=:26/3/60	EG=78	ROM: shoulder, hip, lumbar spine, thoracolumbar spine and trunk lateral flexion. 6-minute walk test. Sit-to-stand test for 30″.	Significant improvement for EG1 and EG2 in shoulder, hip, lumbar and thoracolumbar flexibility, lumbar lateral flexion, 6-min walk test and sit-to-stand test (p<0.05).
Mokhtari et al. [36]	Pre–post-test	To improve balance and depression	EG=15 (F) CG=15 (F)	(62–80)	EG=Pilates method CG=No exercise	EG=12/3/60	EG=36	GDS. FRT. TUG.	Significant improvements in GDS (p=0.007), FRT (p=0.037) and TUG (p=0.001).
Fernández y Benítez [12]	Pre–post-test	To improve muscle mass	EG=15 CG=15 (22 F/8 M)	EG=65.26±6.02 CG=65.33±12.72	EG=Pilates method CG=No exercise	EG=?/3/60	EG=?	Skinfolds caliperation (tricipital, mid-thigh and medial lower leg), muscle perimeters (arm relaxed, forearm maximum, mid-thigh and leg maximum) and hand strength (dynamometer).	No significant differences between groups, although the subjects of EG showed higher values of muscle mass
Fourie et al. [14]	Pre–post-test	To improve flexibility	EG=25 (F) CG=25 (F)	EG=65.32±5.01 CG=66.12±4.77	EG=Pilates method CG=No exercise	EG=8/3/60	EG=24	A standard wall-mounted stadiometer (stature), a calibrated digital medical Scale (bodyweight), Skinfold caliperation, Durnin-Womersley equation (body density) and equation of Siri (body fat percentage).	Significant improvements in shoulder flexion, hip flexion, and lean mass and significant decreases in percentage of body fat and fat mass for EG. Significant improvements in shoulder extension for CG.

Table 2 (continued)

Reference	Design	Intervention focus	Participants	Mean age±SD (range) years	Main session content (E/C)	Intervention (Wk/f/min)	Total Intervention Time for E (hr)	Measurement tools	Findings
Gildenhuys et al. [17]	Pre–post-test	To improve agility, functional mobility and VO2 max	EG=25 (F) CG=25 (F)	EG=66.12±4.77 CG=65.32±5.01	EG=Mat Pilates method CG=No exercise	EG=8/3/60	EG=24	A standard wall-mounted stadiometer (stature), a calibrated digital medical Scale (bodyweight), STS-1, STS-5, pick-up weight test, 8-foot Up and Go test and a 6-minute walk test.	Significant differences were observed in 8-foot Up and Go and pick-up weight test for CG ($p<0.05$), and significant differences were observed in 8-foot Up and Go, pick-up-weight test, STS-1 and STS-5 for EG ($p<0.05$).
Marinda et al. [35]	Pre–post-test	To improve cardiometabolic parameters	EG=25 (F) CG=25 (F)	EG=66.12±4.77 CG=65.32±5.01	EG=Pilates method CG=No exercise	EG=8/3/60	EG=24	Heart rate in resting (after 5 min resting by means of sphygmomanometer and stethoscope), fasting blood glucose, total cholesterol and triglycerides (Reflotron system).	Significant decrease in systolic blood pressure and a significant increase in blood glucose in EG. Any significant changes were observed in resting heart rate, resting diastolic blood pressure, blood cholesterol and blood triglycerides.
Vécseyné et al. [45]	Pre–post-test	To improve physical functioning and quality of life	EG1=22 (17 F/5 M) EG2=17 (13 F/4 M) CG=15 (11 F/4 M)	EG1=66.6±5.5 EG2=67.9±6.9 CG=65.6±6.2	EG1=Mat Pilates method EG2=aqua-fitness class CG=No exercise	EG: 26/3/60	EG=78	FFFT and WHOQOL-OLD questionnaire.	In the FFFT, for both EG, a significant improvement in five out of the seven variables: lower and upper body strength, lower body flexibility, physical mobility (especially dynamic balance) and aerobic endurance. Shoulder flexibility improved significantly in the Aqua fitness group. Lower body strength improved in the CG. BMI did not change significantly in any of the groups. WHOQOL showed improvement in perception and autonomy in the Pilates group and in sociability in the Aqua group.
Hyun et al. [22]	Pre–post-test	To improve balance ability	EG1=20 (F) EG2=20 (F)	EG1=70.0±2.2 EG2=69.3±2.6	EG1=Mat Pilates method EG2=unstable support surface exercises.	EG1=12/3/40 EG2=12/3/40	EG1=24 EG2=24	A biofeedback analysis system was used to examine balance sway length and the speed of the centre of foot pressure. TUG for dynamic balance.	Significant effects on the static and dynamic balance in both groups.

BBS Berg Balance Scale, *CG* control group, *CG1* control group number one, *CG2* control group number two, *EG* experimental group, *EG1* experimental group number one, *EG2* experimental group number two, *F* female, *FFFT* Fullerton Functional Fitness Test, *FRT* functional reach test, *FSST* Four Square Step Test, *GDLAM* Protocol of the Latin-American Development Group for elderly, *GDS* geriatric depression scale, *GGT* Balance test Gleichgewichtstest, *KAT* Kinesthetic Ability Training, *M* male, *Max* maximum, *ML* mediolateral, *MMSE* Mini-Mental State Examination, *NR* not reported, *QoL* quality of life, *RM* repetition maximum, *ROM* range of motion, *STAI* Spielberger Self-evaluation Questionnaire (measuring the level of anxiety), *STS-1* sit-to-stand test with one repetition, *STS-5* sit-to-stand test with five repetitions, *TGUGT* Timed Get Up and Go test, *TUG* Timed Up and Go test, *WHOQOL-OLD* world health organization's quality of life questionnaire, *2D PEAK* a two-dimensional analysis system, *4SBT* sit-to-stand and four scale balance test

Fitness Test (FFFT) which includes a 6-min walking test in its battery of tests [45]. Regarding the two studies in which the 6-min walking test was used, in the study by Gildenhuys et al. [17], no statistical differences were observed between control group (CG) and experimental group (EG), and in the study by Plachy et al. [38], significant improvement was observed for both EGs (EG1, Pilates method; EG2, Pilates method + aqua fitness class) but not in CG. In the study by Marinda et al. [35] that had measured heart rate in resting, a significant decrease in systolic blood pressure was observed in EG. Finally, in the study by Vécseyné et al. [45], a significant improvement in aerobic endurance was observed for both EGs (EG1, Pilates method; EG2, aqua fitness class).

Muscle strength

This aspect was extensively valued among the studies, and different measurement tolls were used [6, 8, 12, 13, 23, 33, 38, 45]. The measurement tools were the following: one repetition maximum (1RM) for knee extension [33], spring-based measurement test for knee extensors and ankle dorsiflexors [6], Muscle Manual Test for different muscles [23], walking up the stairs to assess strength and endurance of lower limbs [8], arm curls 30″ to assess strength of upper limbs [8, 13], sit to stand 30″ to assess strength of lower limbs [13, 38], number of squats until fatigue to assess muscular endurance [13], hand strength by means of a dynamometer [12] and the FFFT which includes a sit to stand 30″ and an arm curls 30″ in its battery of tests [45]. The arm curls 30″ and sit to stand 30″ were the most used, in three occasions for each. Regarding the arm curls 30″, Boguszewski et al. [8] observed a significant improvement after the intervention for EG2 (aqua fitness group) and not for EG1 (Pilates method group), Fourie et al. [13] observed a significant improvement for EG (Pilates method) and CG (no exercise) and Vécseyné et al. [45] observed a significant improvement for both EGs but not for CG. And, regarding the sit to stand 30″, Fourie et al. [13] observed a significant improvement for both EG and CG, Plachy et al. [38] observed a significant improvement for both EGs but not for CG and Vécseyné et al. [45] observed a significant improvement for both EGs and for CG.

Related to the other tools used to assess muscle strength, Mallery et al. [33] did not observe any significant change in knee extensors strength using 1RM for knee extension, Bird et al. [6] did not observe any change in lower limb strength using the spring-based measurement test, Irez et al. [23] observed a significant improvement in muscle strength using Muscle Manual Test, Boguszewski et al. [8] observed a significant improvement in strength and endurance of lower limbs, but only for EG2 (aqua fitness group), but not for EG1 (Pilates method group), using the walking up the stairs test, Fourie et al. [13] observed a significant improvement in muscular endurance for EG, but not for CG, using the number of squats until fatigue test and Fernández et al. [12] did not observe any significant changes in hand strength using a dynamometer.

Body composition

This aspect of physical fitness was only valued in four of the studies included in this review [12, 14, 17, 45]. The aspects valued and assessment tools used were skinfold caliperation [12, 14], muscle perimeters [12], body mass index (BMI) [17], digital medical scale [14, 17], Durnin–Womersley equation to assess body density [14], equation of Siri to assess body fat percentage [14] and FFFT which includes the BMI calculation by means of the Inbody-230 Body Composition Analyser [45].

Fernández et al. [12] observed no significant differences between groups, although the subjects of EG showed higher values for muscle mass, Fourie et al. [14] observed a significant improvement in lean mass and significant decreases in percentage of body fat and fat mass for EG, Gildenhuys et al. [17] calculated the BMI only to assess the previous state of participants in EG and CG in order to establish groups similarities, but it was not measured at the end of the intervention, or at least this post-assessment is not mentioned in the paper, and Vécseyné et al. [45] did not observe any significant change in BMI for both EG and CG.

Flexibility

This aspect was also underestimated among the studies included in this review, only four of the papers value this aspect and all of them do with different measurement tools [8, 23, 38, 45]. The measurement tools used by the authors were sit and reach test [23], reach to the toe test [8], ROM of different joints [38] and FFFT which includes a back scratch test to assess upper body flexibility and a chair sit and reach test to assess lower body flexibility, primarily hamstrings [45].

Irez et al. [23] observed a significant improvement after the intervention for EG using the sit and reach test; Boguszewski et al. [8] did not observe any change after the intervention for both EGs (EG1, Pilates method; EG2, aqua fitness group) using the reach to the toe test; Plachy et al. [38] observed a significant improvement for EG1 and EG2 (EG1, Pilates method; EG2, Pilates group + aqua fitness) in the shoulder, hip, lumbar and thoracolumbar flexibility and lumbar lateral flexion; and Vécseyné et al. [45] observed, for both EGs (EG1, Mat Pilates method; EG2, aqua fitness class), a significant improvement in lower body flexibility and a significant improvement in shoulder flexibility only for EG2.

Neuromotor fitness

This aspect was the most valued by the articles, in 11 of the total 17 articles [4, 6, 8, 17, 19, 22, 23, 36, 41, 43, 45]. The measurement tools were varied, and the most used was the Timed Up and Go (TUG) test to identify the risk of falls [6, 8, 22, 36]. Regarding the TUG, Bird et al. [6] observed a significant improvement for EG, Boguszewski et al. [8] observed no significant progress, Mokhtari et al. [36]observed a significant difference between EG and CG in favour of EG and Hyun et al. [22] observed a significant improvement for both EG and CG.

Other measurement tools used were Berg Balance Scale (BBS) to assess static balance and fall risk, the Kinesthetic Ability Training (KAT) to assess balance [19], the protocol of the Latin-American Development Group for Elderly (GDLAM) to assess functional autonomy [41, 43], the Tinetti test to assess gait and balance abilities [43], different stability/force platforms to assess balance [6, 23], the Four Step Square Test (FSST) to assess dynamic balance [6], the Gleichgewichtstest Balance Test (GGT) to assess static and dynamic balance [4], the Functional Reach Test (FRT) to assess stability [36], the sit-to-stand test 1-repetition (STS-1) and sit-to-stand test 5-repetitions (STS-5) to assess functional mobility of lower limbs [17], the Pick Up Weight Test to assess functional mobility of upper limbs [17], a biofeedback analysis to assess balance [22], the 8-foot Up and Go test to assess speed, agility and dynamic balance [17] and the FFFT which includes the 8-foot Up and Go test [45].

Hall et al. [19] observed significant differences in static balance on the KAT for the three groups (EG1, strength and flexibility program; EG2, Pilates method; CG, No exercise), with EG2 improving more than EG1, and all three groups also presented a significant improvement on the BBS. Rodrigues et al. [41] observed significant improvements for CG and EG in 10-m walking and for EG in getting up from a sitting position, getting up from a lying position, dressing and undressing a T-shirt and getting up from a chair and moving around at home. Rodrigues et al. [43] observed significant post-test differences for EG in balance measured by means of the Tinetti scale and in the General Index of GDLAM. Using a stability/force platform, Irez et al. [23] observed a significant improvement for EG in dynamic balance, while Bird et al. [6] observed significant improvements in static and dynamic balance for EG and in mediolateral sway range on a foam cushion with eyes opened and eyes closed, but no significant differences between group (EG/CG) were observed in any variable.

The FSST was used only in one study [6], and a significant difference was observed only in EG. Coriolano et al. [4] observed significant improvements in body balance for EG on the GGT. Mokhtari et al. [36] observed a significant improvement for EG on FRT with a significant difference between EG and CG. Gildenhuys et al. [17] used the STS-1 and STS-5 to assess functional mobility of lower limbs, Pick Up Weight Test and 8-foot Up and Go Test and could observe significant differences in 8-foot Up and Go and Pick Up Weight Test for CG (no exercise) and significant differences in 8-foot Up and Go Test, Pick Up Weight Test, STS-1 and STS-5 for EG (Mat Piates method). Vécseyné et al. [45] also observed a significant improvement for EG in dynamic balance measured by means of the 8-foot Up and Go Test. Finally, Hyun et al. [22] observed significant effects in static and dynamic balance for both groups using a biofeedback system.

Discussion

This systematic review has been carried out to check the effectiveness of Pilates method on the components of physical fitness (cardiorespiratory endurance, muscle strength, body composition, flexibility and neuromotor fitness) in older people. The objective of this revision makes it different from other published reviews on the use of the Pilates method with older adults. Related to the above-mentioned components on physical fitness, positive evidence was observed regarding neuromotor fitness, especially static and dynamic balance. Related to the other components of physical fitness defined by the ACSM [2] (cardiorespiratory endurance, muscle strength, body composition and flexibility), contradictory results were observed, a fact that requires the need for further studies on those variables. Following the framework in "Results" section, the physical fitness components and the quality of the studies were analyzed in detail.

Cardiorespiratory endurance

Related to such component, the four studies that analyze it do not allow us to draw clear conclusions on the possible benefit of Pilates method on this component of physical fitness. Thus, both Plachy et al. [38] and Vécseyné et al. [45] observed significant improvements in the 6MWT, but for both EGs, the one who was intervened with Pilates method and the one who was intervened with aqua fitness, with respect to CG. In both studies, the result differences between EGs are not mentioned, and there is also no mention on the control of possible variables that could be influencing the positive results, like the degree of physical fitness activity carried out outside the established intervention. This would be an important aspect to evaluate, given that both studies were the long lasting of the analyzed studies, 26 weeks of intervention. The long duration of the studies could encourage the participants in participating in other physical activities than the established intervention, something that let us to think that the observed benefits could be related to additional physical activity and not to the intervention program, as we cannot affirm that the benefits observed by Pilates method are better than the benefits by aqua fitness.

Additionally, in the study by Gildenhuys et al. [17], no significant differences were observed related to cardiorespiratory endurance on the 6MWT.

Those data and the fact that the studies that valued cardiorespiratory endurance were rated as low-quality studies according to PEDro scale leads us to state that there is a limited evidence on the effectiveness of the MP on cardiorespiratory endurance.

Muscle strength

Regarding muscle strength, we could start differentiating the studies that value muscle strength of upper limbs [8, 12, 13, 45] and those that value muscle strength of lower limbs [6, 8, 13, 23, 33, 38, 45].

In the case of those studies that valued muscle strength of upper limbs, Boguszewski et al. [8] and Fernández et al. [12] did not observe a significant improvement in strength of upper limbs for EG when compared to CG. Positive results were observed for EG in the other two studies [13, 45], but in the study by Fourie et al. [13], a significant improvement was also observed for CG, and in the study by Vécseyné et al. [45], no significant differences were observed when comparing EG (Pilates method) and CG (aqua fitness group). Perhaps the explanation of these results could be the fact that the total time intervention and workload was higher in those studies in which positive results were observed. Given the results obtained and the fact that only the study by Fourie et al. [13] is a high-quality study according to PEDro scale, we could state that there is limited evidence on the capacity of Pilates method in developing muscle strength of upper limbs in older adults.

With regard to those studies that valued muscle strength of lower limbs, data obtained are not better, and, therefore, the evidence on the effectiveness of the method in improving muscle strength of lower limbs is also limited. In this case, some studies report significant improvements for Pilates groups [13, 23, 38, 45], but some of them report no significant improvements [6, 8, 33], or positive results were also observed for CG and/or for other EG, and in this case, no significant differences were observed between groups [13, 38, 45]. As with the results on upper limbs strength, the better results are observed in the studies with long-lasting interventions, something that suggests a minimum workload related to the improvement in muscle strength after a Pilates intervention.

Body composition

With regard to this component, one study reports significant improvements in lean and fat mass and in body fat [14], but other studies report no significant differences in BMI [45] or muscle mass [12]. The study by Gildenhuys et al. [17] reports no significant post-intervention results. Therefore, there are contradictory results, and also, all the studies in which this aspect is valued are low-quality studies according to PEDro scale; this is why we could state that there is no evidence of the positive effects of Pilates method in body composition on older adults.

Flexibility

There seems to be a moderate evidence of the benefits of Pilates method on flexibility of lower limbs. There is a high-quality study [23] and two low-quality studies [38, 45] which present significant improvements on flexibility after a Pilates method intervention. However, such improvement does not seem to occur in shoulder joint, except for the study by Plachy et al. [38]. This could be caused by any factor associated to the programs developed in the different studies, but this is an unknown aspect. It is recommendable that future research describes the composition of their intervention programs based on Pilates method, enabling to compare programs and to analyze results in a proper way.

Neuromotor fitness

In relation to this component, it is worth noting that it is the widely aspect valued among the analyzed studies. Thus, 11 of the 17 studies assess balance in their sample [4, 6, 8, 17, 19, 22, 23, 36, 41, 43, 45]. Among them, significant benefits on static balance [6, 19, 22, 43] and dynamic balance [4, 6, 17, 23, 36, 41, 43, 45] are observed. The only study in which no significant results are observed is the one by Boguszewski et al. [8]. For both aspects of balance, there seems to be a strong evidence about the benefits of Pilates method on older adults indicated by the two high-quality studies and other low-quality studies according to PEDro scale that confirm those positive results. Such results also could award Pilates method a preventive tool in diminishing risk of falls in older adults and consequently in diminishing fractures prevalence and their functional and social consequences.

Study quality

The studies analyzed are low-quality studies in general lines (mean 3.8±1.2; range between 1 and 6). On the one hand, the main items achieved by the 17 analyzed studies according to PEDro scale were those related to "Point Measure and Variability", "Groups Similarity at baseline", "random allocation" and "between-group comparisons" (see Table 1). On the other hand, in none of the analyzed studies, subjects and therapists were blinded, and only in one study the assessor was blinded [23], only in two studies the "follow-up 85 %" criterion was met [6, 33] and only three studies met the criteria "concealed allocation" or "intention to treat analysis" [4, 6, 19]. Therefore, data on quality assessment suggest that the strong points of the studies are related to the allocation of the sample and data analysis, while weak points are those related to blinding and the explicit information on dropouts and the lack of the intention to treat analysis. Although in several clinical trials it is difficult to blind subjects and therapists, it would be interesting that pieces of information on dropouts were detailed because of the possible influence of this aspect on the determination of group differences. The failure to meet the criteria of "follow-up 85 %" and "intention to treat analysis" introduces a bias that directly affects internal and external validity of any study.

In short, the low scores in PEDro scale by the analyzed studies mean their weakness in the experimental methodology, especially due to the lack of blinding, dropouts control, intention to treat analysis and allocation concealing. Such weakness is also reinforced by other aspects like the lack of standardized intervention protocols based on Pilates method (number of sessions per week, intervention duration, duration of each session, sample characteristics and if therapists are certified in Pilates method). All this could be also a reason to understand the fortitude of the evidence about the benefits of Pilates method on physical fitness components in older adults as limited.

Study limitations

Further to the above-mentioned on methodological quality of the studies, other limitations could be mentioned. First, samples are scarce in general. Only the study by Irez et al. [23] counts with 30 subjects in each experimental and CG. Additionally, in none of the studies, the calculus on the representative sample of each population was carried out, a fact that complicates the extrapolation of the observed results. In most of the studies, the sample is formed only by women [8, 13, 14, 17, 22, 23, 35, 36, 41, 43] and in one study by hospitalized patients [33]. Some of the observed differences regarding the results could be due to sample ages. Although, in all of the studies, 65 years or older is the average age; this is also true that the ranges, in those studies in which they are indicated, are quite variable. This revision includes studies with age ranges of 65 to 74 years [4], age ranges of 55 to 76 [8], of 60 to 78 [38] or of 62 to 80 [36].

Other important limitation of the analyzed studies regards the developed Pilates program. There are several differences among the programs and, also, the lack of information on the specific exercises used, something that complicates the replication and, consequently, the comparison of such studies. In one study, the duration of the intervention is unknown and, consequently, it is also unknown the workload burden to the EG [12]. There are studies with a total intervention time from 4 [33] or 5 weeks [7] to 26 weeks [38, 45]; one includes one session per week [8] and some include three sessions [6, 12–14, 17, 22, 23, 33, 35, 36, 38, 45]; some include a duration of the session of 30–40 min [22, 33] or 90 min [8]; some include a total intervention time under 20 h [6, 8, 33, 41, 43] or over 30 h [23, 36, 38, 45]. It would be appropriate for a greater uniformity on protocols in order to make possible comparisons between studies and the replication of the study.

Given the above-mentioned, future researches should include bigger and representative samples, a random and concealed allocation of subjects into experimental and CGs, blinding of subjects and assessors, dropouts control, the detailed protocol intervention (exercises, number of repetitions, duration and frequency of the sessions and the number of the total weeks intervention).

Conclusions

In conclusion to this systematic review, we could note, by one hand, the strong evidence about Pilates method on the improvement of static and dynamic balance in older adults, while there is a moderate evidence of the effects on flexibility of lower limbs. On the other hand, we could also conclude that the analyzed studies have a low methodological quality, something that raises the need of more rigorous studies with bigger samples, the concealed and random allocation of the sample, blinding, dropouts control and an intention to treat analysis.

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Author's Contribution Jose Cancela role: Designed research-Performed research-Analysed data. Iris M. Oliveira role: Performed research- Wrote the paper- Analysed data. Gustavo Rodriguez-Fuentes role: Performed research- Analysed data.

Declaration of original contribution We declare that the submitted paper, the data and results have not been published anywhere.

Informed consent for human studies/ Animal studies Disclosure of interest J.M. Cancela Carral, Iris M. Oliveira and Gustavo Rodriguez-Fuentes declare that they have no conflicts of interest concerning the article.

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